CRANFIELD UNIVERSITY

MUHAMMAD AKRAM AFZAL

RISK MANAGEMENT IN NEW PRODUCT DEVELOPMENT: A SYSTEMATIC REVIEW OF LITERATURE

SCHOOL OF MANAGEMENT
MRES DISSERTATION

MASTER OF RESEARCH
Academic Year: 2011 - 2012

Supervisor: DR. MAREK SZWEJCZEWSKI
October 2012

CRANFIELD UNIVERSITY

SCHOOL OF MANAGEMENT
MRES DISSERTATION

MRES

Academic Year 2011 - 2012

MUHAMMAD AKRAM AFZAL

RISK MANAGEMENT IN NEW PRODUCT DEVELOPMENT: A SYSTEMATIC REVIEW OF LITERATURE

Supervisor: DR. MAREK SZWEJCZEWSKI
October 2012

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Research

ABSTRACT

The purpose of this thesis is to provide taxonomy of risk management (RM) in new product development (NPD) research and, based on that, to develop a research agenda for this field of study. The review was based on a systematic review which not only concentrates peer reviewed journal papers but also conferences and a book chapter. A total of 58 academic sources have been retrieved published within the period of 1980-2012 and were classified into various purposeful themes. The review reveals that research on RM in NPD is mostly theoretical in nature and lacks empirical foundations. It also argues that while there has been written a lot on how risk should be managed in NPD process (prescriptive type), the other aspect of how risk is being managed (descriptive type) is not very well addressed. Based on this, various research gaps are identified from different developed themes. The review is limited in several ways. First, research cannot be regarded as complete or comprehensive literature review in the field of RM in NPD, although every effort has been made to include the articles relevant to review question. The themes selected for classification of articles could have been structured in many different ways. The research accomplishes an identified need for exhaustive classification of literature. It identifies discrepancies among theoretical and empirical knowledge and thus tries to bridge a gap between both types of knowledge.

Keywords:

Risk management, new product development, Literature review, risk taxonomy, risk management processes

ACKNOWLEDGEMENTS

With deep humility, I thank Almighty God, the merciful and beneficent, for his constantly reliable help and his everlasting inspiration.

I would like to express my deepest thanks and appreciation to my thesis supervisor Dr. Marek Szwejczewski, for his consistent help, guidance and attention that he devoted throughout the course of this work. His valuable suggestions and useful discussions made this work interesting to me. His support and words of encouragement gave a new life to my efforts in hard times. Without his help and valuable directions, this work would have never seen the light. I wish to thank him from my heart.

Many great thanks to thesis panel members Dr. Collin Pilbeam and Heather Woodfield for their interest, cooperation and insightful feedback. I am also grateful to Dr Mohammad Ben Daya for constructive discussions during my visits to King Fahd University of Petroleum & Minerals, Saudi Arabia.

I am also grateful to the Director, PhD program, Dr. David Denyer, Director, MRes program Dr. Ruth Sealy and other staff members including Dr Donna Ladkin,, Wendy Habgood,, Irena Pidlyskyj my cohorts Farooq Habib, Hendro Adiarso, Anandadeep Mandal , Carmine Basile and Katherina Windler. I cannot thank them enough for their help and support.

The support and facilities provided by Cranfield School of Management for completing this work are highly appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Introduction

1.1 General Motivation

Globalization and increasing competition in businesses promote a dynamic and turbulent environment where customers expect fast product delivery at cheap prices with better quality (Ulrich et al., 2012). The task of new product development (NPD) gets increasingly complex as it has to satisfy and integrate preferences of multitude of internal and external stakeholders to formulate an optimal set of specifications (Sommer et al., 2008). Thus it requires not only the knowledge from various disciplines such as engineering, marketing and manufacturing (Ahmadi and Wang, 1999) but also an integration of various functions such as marketing, R&D and planning etc. (Ulrich et al., 2012).

The task of NPD becomes more challenging as companies are focusing towards their core competencies and outsourcing noncore competencies to third parties (Thomas , 2009). This leads to a "lower degree of internal value creation and increases the importance of partners along the supply chain" (Oehmen et al., 2010, p.1). While these partners bring improvements and further business opportunities in NPD process, they present additional complexities as well (Thomas, 2009). Although NPD is considered as valuable source of competitive advantage (Mu et al., 2009), due to the internal and external complexities, and challenges, it is a risky endeavour (Oehmen et al., 2010).

1.2 Cases of Motivation

The US aerospace and defence industry is currently facing massive cost and schedule overrun for more than 96 defence related products (GAO, 2011). According to the report of government accountability office (GAO) regarding F-35 (one of innovative types of air craft), due to extensive amount of testing and alteration of production processes, an overall amount of the 289 million dollars were additionally allocated for the F-35 project alone which further require massive additional time to complete its first production. Additionally, GAO cites that "Managing an extensive,

still-maturing global network of suppliers adds another layer of complexity to producing aircraft efficiently and on-time" (GAO, 2011, p. 74).

Boeing decided to design an innovative airplane "787 Dreamliner" to achieve revenue growth and market attention. Despite taking significant management efforts, capital investment and the use of unconventional supply chain such as involving suppliers as a strategic partner rather than traditional material/ spare parts providers only, Boeing faced series of delays and excessive cost (Tang et al., 2009).

In both cases, lack of effective risk management (RM) was cited as one of the main underlying reasons for unexpected project delays and excessive cost (GAO, 2011; Bassler et al., 2011; Tang et al., 2009).

1.3 Context of the Systematic Review

To address and overcome potential process or product failures, the literature acknowledges the management and reduction of risk as central element of NPD. It is considered as an important tool for minimizing risks and increasing the likelihood of success of a NPD projects (Bassler , 2011). Mu et al. (2009) posit that RM strategies contribute both individually and interactively in influencing the success of NPD projects.

Despite its significance effect on NPD performance and success, extant literature cites various cases which show how organizations are struggling in managing NPD related projects risks. According to a cross organizational case study by Raz et al. (2002), only limited amount of NPD projects use any kind of RM practices. Olechowski et al. (2010) observe that while there is multitude of research published on different RM practices in NPD context; the key characteristics of RM processes are not clearly understood among practitioners and researchers. The two recent cases of F-35 (GOA, 2011) and Boeing (Tang et al., 2009), and the evidences from extant literature (Raz et al., 2002; Olechowski et al., 2010) show that risk management practices are being ignored in practice and their potential benefits are fully understood among practitioners and academicians. The fact motivates me further to unveil the shortcomings and gaps in the literature of RM in NPD. From a personal

perspective, the main goal of my research it to address risk related challenges which organizations are facing.

1.4 Thesis Organization

The thesis is organized as follows.

Chapter 1 gives the introduction and an overview of thesis objectives.

Chapter 2 discusses the aspect of “mapping the field”.

Chapter 3 describes the approach and methodology used for achieving systematic literature review.

Chapter 4 describes descriptive statistics of the main findings.

Chapter 5 reports the main findings of the 58 articles in terms of various themes.

Chapter 6 presents discussion section where findings from various themes are synthesized and accumulated. This also includes potential research gap and future research work.

Chapter 7 presents the conclusion which includes limitations of research, contribution to theory and practice.

2 Mapping the Field

2.1 Research Goal and Approach

The purpose of the study was to develop possible review question(s) that would inform my subsequent systematic literature review. The scope of the study lies at the common intersection between RM and NPD processes (see Figure 1).

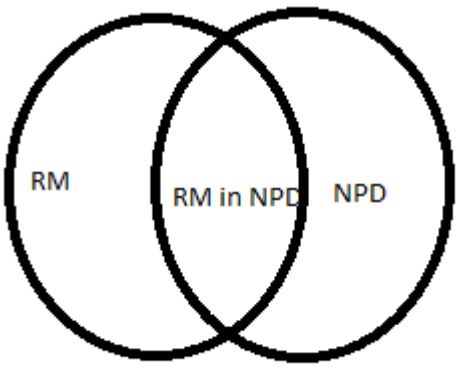

Figure 1 Research Domains

2.2 Executive Summary of the Scoping Study and Positioning of the Review Question

To address and overcome potential process or product failures, the literature acknowledges the management and reduction of risk as a central element of new product development (NPD). Despite its significance effect on NPD performance and success, extant literature cites various evidences where organizations are still struggling in managing NPD related projects risks (Raz et al., 2002; Olechowski et al., 2010). This thesis sought to find the research gap on RM in NPD domain. While key articles on RM and NPD domains are reviewed, articles relevant to interplay between RM and NPD are also systematically analysed.

The article starts with general introduction on risk history followed by general definitions of risks and their management. In this regard, the article provides an overview of various theories in risk with special focus on clarifying and

distinguishing important concepts such as nature of risk (whether subjective or objective), and difference between risk and uncertainty. In addition to that, selected existing RM processes from researchers, government organizations and professional societies are briefly reviewed.

It is concluded that research on risks and its management has a long history. Furthermore, disputes among researchers on the nature, definitions and scope of risk are observed. Most of researchers which investigate risks in NPD context do not seem to recognize about these debates. Some authors though tried to use words like "perception" or "perceived" which indicates subjective nature of risk, most authors' conceptualize risk objectively by associating probability with it. While majority of authors have fragmented view on the concept of risk and uncertainty, researchers use both terms interchangeably in the context of NPD. Also, risk definitions are varied in terms of scope, meaning and consequences in NPD context. Extant literature on general RM provides some evidences which show that different perception on the nature of risks strongly influences the manager's decision about selection of tools and strategies. However, such evidences are lacking in the context of NPD. Therefore, it is of particular interest to explore these debates in the context of NPD.

Next, selected RM processes are reviewed. Some of these are relevant to NPD such as RM process designed for defence related products (DoD, 2006) and RM framework for lean NPD by Oehmen, (2005). A major limitation observes in these processes is the lack of any empirical evidence. No any literature source was identified from the NPD context which provides empirical evidences of these processes. While all these processes share common element i.e. lacking any empirical evidence, a general agreement on definitions and activities of RM processes is observed. Three standard activities shared by all processes are risk identification, risk assessment and risk treatment. Conversely, some activities are not shared by these processes. Some of these activities are at the outset of process such as communication and consultation, establishing the context and planning etc. Some of the processes address risk analysis and risk evaluation separately. Many processes consist of additional activities needed at the end of process such as risk monitoring and evaluating. There could be various reasons for these additional activities and

steps. Process which consists of only standard activities such as risk identification, risk assessment and risk treatment should not be regarded as an incomplete process. Presumably, the scope of additional activities might have covered under the paradigm of standard activities. For example, steps prior to risk identification in ISO 31000 RM (ISO, 2009) process are communication and consultation and establishing the context. Process like (Royal society, 1992) which does not have these uncommon activities might have considered the scope of these under the phase of risk identification. Another possibility would be the lack of significant importance of these activities which prevent societies or authors not to include them in their respective RM processes. It should be of particular importance to investigate the scope of standard versus nonstandard or uncommon activities in great extent.

In order to understand, to what extent literature in NPD is conforming different RM elements, key articles within the domain of NPD are structured along three standard elements i.e. Along risk identification, risk assessment and risk evaluation. This helps us to see which of these elements are addressed in a greater extent and which are not.

It is noted that these three elements of RM process are addressed to varying degree. A brief overview of literature findings related to these elements is provided below.

The risk identification phase not only identifies risk but also assesses causal relationships between risk and outcome. A key activity in this regard is to develop a typology of risks i.e. categorizing and classifying risks. Categorizing risks provides help in diagnosing causal relationship between risks and its outcome and risk can be structured and positioned in useful manner. Categorizing risks in some structure and optimum way is always understood as a challenging task both for academicians and practitioners (Mu et al., 2009). In the context of NPD, various risk typologies are proposed. While many studies present risk classification from different perspectives i.e. in different product types and contexts, technology, market and organizational risks are more frequent than others. It can also be concluded that all major risks can be subsumed by these three main types. A question can be raised here to what extent these risk typologies represents or align with the challenges faced by NPD process in

current turbulent environment. For example, risks related to supply chain appeared to be very prominent in this decade and a lot of research has been carried out in this regard through different angles. However supply chain related risks in the context of NPD are not very well addressed. Among the key articles which provide risk typologies, only 2 studies (Oehmen and Seering ,2011; Keizer and Halman, 2007) considered supply chain related risks. Hence, there is no any strong evidence which shows the extent to which these typologies are comprehensive in addressing the risks. This phenomena need to be explored further.

In risk evaluation phase, most techniques used by firms are subjective in nature. Although some objective approaches are also there such as probability impact matrix etc., by considering its high importance in NPD literature more research is required especially from the objective perspective of risks.

In regard to risk treatment, various observations are observed. The analysis of risk treatment phase in general risk management domain reveals broad classification of risk treatment strategies: speculation, postponement, transfer, avoidance, control, security and hedging strategies. Conversely, risk treatment strategies in the context of NPD are marginally addressed. Only a limited number of approaches such as postponement, mass customization, cross functional integration and gaining proficiency etc. are proposed. An exploratory analysis where these few proposed treatment strategies can be compared to broader classification scheme from general RM literature is required to determine the particular type of strategy require more attention of researchers.

The article summarizes and synthesizes findings from NPD literature and compares them according to different phases of RM process.

Articles are also analysed according to different literature type. Various articles provide empirical studies which investigate the importance of RM process and its effect on NPD performance. One article analysed specific RM capabilities of various NPD processes such as Stage Gate, Spiral etc. It is found that existing literature recognizes the importance of product development frameworks as RM process since they provide an organized approach for managing risks in NPD. However, lack of

empirical evidences is observed as only limited amount of papers investigate RM process empirically.

In summary, various discrepancies and shortcomings are observed in the literature. These are

- The debates on the nature of risks and difference between risk and uncertainty in the context of NPD and their possible impacts on NPD risk management performance.
- Lack of any empirical sources for RM processes relevant to NPD.
- Lack of analysis on assessing difference in various RM processes elements, for example standard elements versus nonstandard elements.
- Lack of analysis on understanding the extent to which existing risk typologies represent or align with the challenges faced by NPD process in current turbulent environment
- Lack of objective approaches in risk identification and risk assessment.
- Lack of analysis on risk treatment strategies
- Lack of empirical evidences of RM practices and their successful characteristics in different industrial contexts and their effect on NPD performance
- Lack of empirical evidences on the capability of risk management of different NPD framework such as Stage gate and Spiral processes. To what extent, they are capable of capturing various dimensions of risks and specifically for example, are they able to capture and cope with supply chain risks also.
- Lack of any holistic RM process and framework

Since the overall literature covered in scoping study is not sufficient to justify these shortcomings, it is decided to perform a thorough and comprehensive systematic review by considering reasonable amount of literature. Therefore I would like to explore following main review question for systematic review.

Review Question: How risks are managed in new product development process (NPD)?

The review question is classified into two main aspects: prescriptive aspect and descriptive aspect. The prescriptive aspect of the review questions intended to design in order to locate research which informs how risks should be managed. This type of research may include both theoretical and empirical papers. Based on the prescriptive aspect of the research, following sub review question is formulated.

RQ1: How risks should be managed?

The descriptive aspect of the research informs the evidences which show how risk is being managed in reality. What firms, companies are doing in practice to manage risks regardless of whether they are doing it in a right way or wrong. Based on the descriptive aspect of the research, following sub review question is formulated.

RQ2: How risks are being managed?

3 Methodology

3.1 Introduction

Systematic review is considered as a methodology that follows transparent, replicable and explicit methods " to locate existing studies in particular field, select and evaluate scholarly contributions from these existing studies, analyse and synthesize main findings and finally report the findings or outcomes" (Tranfield, Denyer and Smart, 2003: 208) in an appropriate way.

The scoping study conducted leading to this review highlighted that despite its significance among academics and practitioners: a) research work on RM in NPD was limited; b) there were no articles that review, organize and synthesize the existing literature in this field of inquiry. Based on its practical implications and current need of industry, the topic was considered relevant for research both from a theoretical as well as practical perspective.

3.1.1 Aim of the Review

The aim of this work is to systematically review the extant literature on RM in NPD to develop a set of possible research questions that will form the basis for the subsequent PhD research work.

3.1.2 Review Question

Informed by the shortcomings observed during the scoping study of the existing literature on RM in NPD, the following main review question and subsequent sub review questions were developed:

Review Question: How risks are managed in new product development process (NPD)?

Sub-Review Question 1: How risks should be managed (prescriptive view)?

Sub-Review Question 2: How risks are being managed (descriptive view)?

3.1.3 Structure of the Chapter

This chapter is structured as follows. First, the stages of the systematic review are presented. Second, the details regarding the selection of consultation panel are discussed. Third, the design of research strategy that encompasses development of search strings and selection of appropriate databases is explained. Fourth, the selection criteria and quality appraisal standards are developed. Finally, the details regarding the data extraction and synthesis processes are provided.

3.2 The Systematic Review Protocol

Based on the structure presented by Cranfield School of Management (www.cranfieldonline.com) , the review protocol used for this work is as follows:

Phase A: Planning the Review

- Selecting a consultation panel
- Mapping the field(s)
- Developing a search strategy

Phase B: Identifying and Evaluating Studies

- Conducting a systematic search
- Selecting and evaluating studies

Phase C: Extracting and Synthesizing Data

- Conducting data extraction
- Conducting data synthesis

Phase D: Reporting and Utilizing the Findings

- Reporting the findings
- Utilizing the findings

The first three phases of this framework are discussed in this chapter while the discussion related to the phase D is presented in Chapters 4 and 5 and 6.

3.3 Phase A: Planning the Review

During the planning phase of the review, a search protocol was developed comprising the following three stages: a) Selecting a consultation panel; b) Mapping the field(s); and c) Producing a review strategy. The second stage of this phase, i.e. mapping the field, is already presented in Chapter 2. The remaining two stages are explained as follows.

3.3.1 Selecting a Consultation Panel

The objective of this stage is to establish a consultation panel that provide expert guidance in: a) identification of suitable sources; b) development of inclusion/exclusion criteria for selecting articles literature; and c) establishing quality appraisal criteria. Consultation panel members are both from within and outside the Cranfield School of Management. The names, organizations and expertise of the three panel members are presented in Table 1.

Table 1 Consultation Panel

Name	Organization	Expertise
Dr. Colin Pilbeam	Cranfield School of Management, Cranfield University	Literature review process
Dr.Marek Szwejczewski	Cranfield School of Management, Cranfield University	Content (New product development; Risk management)
Dr. Mohammed Bendaya	King Fahd University Petroleum and Minerals	Content (New product development, Risk management)
Heather Woodfield	King Norton's Library, Cranfield University	Information specialist

Dr Colin Pilbeam:

Dr Pilbeam is an expert in the area of natural and social sciences and an experienced academic researcher. His help was instrumental in developing and executing a

transparent search protocol to systematically review the extant literature on NPD and RM.

Dr Marek Szwejczewski:

Dr Szwejczewski is the PhD supervisor appointed for this research work. He is a reader at Cranfield School of Management and subject expert in NPD and RM. His guidance was critical in improving the quality of this work during every stage of the process. Dr. Szwejczewski also provided the necessary support and invaluable feedback that helped in the completion of this research work on time.

Dr Mohammed Ben-daya

Dr Mohammed Bendaya is professor at King Fahd University of Petroleum and Minerals, Saudi Arabia and subject expert in NPD, RM and supply chain. He provided invaluable feedback in terms of article selection and review process.

Ms Heather Woodfield

Ms Woodfield is an information specialist at the King Norton's Library in Cranfield University. She was consulted during the process of developing suitable search strings and selection of appropriate databases.

3.3.2 Mapping the Field

This part of the phase A is already discussed in Chapter 2.

3.3.3 Developing a Search Strategy

The search strategy adopted for this review consisted of the following steps: a) selection of relevant databases; b) identification of key words; and c) development of search strings. These three steps of the search strategy are explained below.

3.3.3.1 Selection of Relevant Databases

Initially 4 databases were considered for the systematic review: 1) ABI/Inform Global; 2) EBSCO; 3) Scopus; 4) Web of Knowledge. The choice of these databases was based on

i) Expert opinion of panel members after having discussion with them including supervisor Dr. Marek Szwejczewski, information specialist Heather Woodfield and external panel member Dr. Mohammed Ben-Daya.

ii) Among these four databases, ABI, Web of Knowledge and Scopus are most comprehensive business and social science databases which not only covered a wide time period but also the literature domain of RM in NPD. All major journals prominent in the domain which either published more frequently in the discipline such as International Journal of Physical Distribution and Logistics Management, Research Technology Management, Technovation and Journal of Engineering Design were revealed by these databases. Also, other journals which have greater impact on RM and NPD such as Risk analysis, Technovation, Research Technology Management, Journal of Product Innovation Management, Journal of Product and Brand Management, Journal of Engineering Design, International Journal of Risk Assessment and Measurement and International Journal of Product Development were revealed by these 3 databases. Their relevance for the literature on RM in NPD as search strings revealed huge number of hits from each of these data bases. I.e. ABI INFORM (1,565), Scopus (1200) and Web of Knowledge (1905).

Just for the purpose of triangulation and to see whether other databases provide any additional source, small databases such as Science Direct, Emerald and Google Scholar were also examined. The output of each of these databases were recorded in bibliographic software EndNote and later compared with the outcome of search strings in 4 main databases. To the best of our knowledge, all articles appeared from small databases were already revealed by 4 main databases. Thus, by keeping in mind the results of comparison of both types of databases and expert opinion of information specialist Heather, it was decided to discard the small databases.

The other rationale for selecting these databases is provided in Table 2.

Table 2 Rationale for Selecting Databases

Databases	Rationale
ABI\INFORM Global	One of the most utilized and comprehensive databases used for academic research in social science
EBSCO	Another major source for academic literature in social science. Though, there was an overlap on the literature sources retrieved from ABI and EBSCO, but some key sources were only covered by only one of them
Scopus	It is considered as one of largest database for peer reviewed literature and particularly provide an opportunity to perform search beyond the management literature, thus allowing an exhaustive search in broader disciplines
Web of Knowledge	It consists of broader range of databases pertaining information on multitude of disciplines in the form of scholarly journals, books, reports and conferences etc.
Science Direct	This data base was used to crosscheck if any source is missed from the aforementioned databases.
Emerald	This data base was used to crosscheck if any source is missed from the aforementioned databases.
Google Scholar	A quick search was performed with the help of this database

Other sources such as books, conference papers were also considered as possible sources of information.

3.3.3.2 Identification of Keywords

The review question used for this work is as following:

How risks are managed in new product development process (NPD)?

The two main constructs of this review question are "*Risk Management*" and "*New Product Development*". These two main constructs were further subdivided into four categories as shown in Table 3.

Table 3 Constructs from the Review Questions

No	Constructs from the Review Question	Sub Categories
1	Risk Management	Risk
		Management
2	New Product Development	New Product
		Development

Informed by the scoping study and by the recommendation of the panel members, a list of key words was identified. Table 4 shows these keywords and their link with the review question.

Table 4 List of Identified Key words

No	Constructs	Key Words
1	Risk	1. Risk*
		2. Threat*
		3. Turbulence*
		4. Barrier*
		5. Uncertaint*
		6. Issue*
		7. Hazard*
		8. Vulnerabilit*

2	Management	1. Management
		2. Identification
		3. Assessment
		4. Evaluation
		5. Planning
		6. Control
		7. Mitigation
3	New Product	1. Product
		2. Products
		3. New Product
		4. New Products
		5. P*
		6. NP*
4	Development	1. Development
		2. Introduction
		3. Design
		4. Innovation
		5. D*
*NOTE: New Product Development is also referred to as PD and NPD in the literature		

In order to use them in the search strings in the coming section, constructs 1 and 2 (risk and management) were integrated (Table 5). Similarly, construct 3 and 4 (new product and development) were combined (See Table 6).

Table 5 Combining constructs 1 and 2

	Combined Constructs 1 &2	
1	**Risk Management**	Risk Management
		Risk identification
		Risk assessment
		Risk evaluation
		Risk control
		Risk Planning
		Risk monitoring
		Risk mitigation
		The remaining alternatives of "risk" such as hazard, uncertainty, and threat were used as a single entity in the search command rather than integrating with "management" constructs.

Table 6: Combining constructs 3 and 4

	Combined Constructs 3 &4	
1	**New Product Development**	product development
		product introduction
		product design
		new product*
		product innovat*

		New product development
		NPD
		PD

3.3.3.3 Development of Search strings

The combined key words listed in Table 5 and 6 were used to develop 4 search strings using Boolean Connectors (AND, NOT, AND NOT). The two search strings developed from the key words related to the terms “risk” and “management” are shown in Table 7.

Table 7 Search Strings for the “Risk Management”

No	Description
Search String 1	"(risk management" OR "risk identification" OR "risk assessment" OR "risk evaluation" OR “risk planning” OR “risk control” OR “ risk treatment” OR risk* OR hazard* OR uncertain* OR turbulen* Or issue* OR barrier* OR vulnerabilit* OR threat*)”
Search String 2	“(Risk w/3 (manag* OR identif* OR assess* OR evaluat* OR plan* OR control* OR treat*) OR risk* OR hazard* OR uncertain* OR turbulen* OR issue* OR barrier* OR vulnerabilit* OR threat*)”

Similarly, the two search strings developed from the key words related to the terms “new product” and “development” are shown in Tables 8

Table 8 Search Strings for the "New Product Development"

No	Description
Search String 3	"(product development" OR "product introduction" OR "product design" OR "new product*" OR "product innovat*" OR NPD OR PD OR "new product development)"
Search String 4	"((Product* w/3 (develop* or introduc* or design* or innovate*)) OR NPD OR PD OR "new product development")

3.3.3.3.1 Rejected Search Strings

It is worth mentioning here that, for the construct of "New Product Development", two other search strings were developed to test whether there was any difference in the number of records identified. However there was not any significant difference recorded. Therefore these two search strings were discarded. These discarded search strings are shown in Table 9.

Table 9 Rejected Search Stings

No	Description
Search String 5	1**)**(Product* w/3 (develop* or introduc* or design* or innovate*) OR NPD OR PD OR "new product development") w/10 (Risk w/3 (manag* or identif* or assess* or evaluat*) OR hazard* OR uncertain* OR turbulen* Or issue* OR barrier* OR vulnerabilit* OR threat*)
Search String 6	2) (Product* w/3 (develop* or introduc* or design* or innovate*) OR NPD OR PD OR "new product development") w/15 (Risk w/3 (manag* or identif* or assess* or evaluat*) OR hazard* OR uncertain* OR turbulen* Or issue* OR barrier* OR vulnerabilit* OR threat*)

3.3.3.3.2 Search String Combinations

Various possible combinations of the four strings shown in Tables 5 and 6 were tested to by searching ABI/INFORM database. The results are shown in Table 10.

Table 10 Results from Possible Search String Combinations

No	Possible Search String Combination	No. of Hits
1	Search String 1 and Search String 3	676
2	Search String 1 and Search String 4	689
3	Search String 2 and Search String 3	912
4	Search String 2 and Search String4	1,565

3.3.3.3.3 Final Search String

These results indicated that combination number 4 between search string 2 and search string 4 recorded the maximum number of hits and hence was considered as most relevant to search the remaining databases. Thus the final search string used for this systematic literature review is as follows.

"(Product* w/3 (develop* or introduc* or design* or innovate*)) or NPD OR PD OR "new product development") And (Risk w/3 (manag* or identif* or assess* or evaluat*) OR uncertaint* OR risk* OR hazard* OR uncertain* OR turbulen* Or issue* OR barrier* OR vulnerabilit* OR threat*)"

3.4 Phase 2: Identifying and Evaluating Studies

During the second phase of this systematic literature review, the articles relevant to this work were identified and evaluated. This phase comprised the following two stages: a) conducting a systematic search; b) selecting and evaluating the studies.

3.4.1 Conducting a Systematic Search

The final search string (shown above) was used to systematically search the four databases. The results of this search are shown in Table 11.

Table 11 Number of Hits Recorded by Using the Final Search String

No	Databases	Recorded Hits
1	ABI/INFORM	1,565
2	EBSCO	451
3	Web of Knowledge	1,905
4	Scopus	1,200
	Total Number of Recorded Hits	5,121

The total number of recorded hits was 5,121. These articles were taken forward into the second phase of the review for evaluation. This is discussed as follows.

3.4.2 Selecting and Evaluating the Studies

The process of the selecting and evaluating the studies consisted of the following three steps.

i) Selection based on title and abstract review

ii) Selection based on full text review

iii) Quality Appraisal

3.4.2.1 Selection based on title and abstract review

During the first step of the selection process, the titles and abstracts of 5,121 articles were reviewed. It was found that search strings revealed a lot of unintended and irrelevant articles. For example, the words like “threat” and “hazard” along with the words product revealed those research articles which were specifically associated to medical and chemical products and thus totally irrelevant. Similarly, the words like “issues” created a lot of misconception and revealed a lot of articles which were irrelevant at all. Also, it was observed that words like “threat, hazard and issues” created a lot of misconception and did not appear to be helpful to greater extent in locating the articles relevant to my review question. Those articles which did not fulfil the criteria mentioned in the Table 12 and 13 were also rejected. At this stage 4,198 articles were excluded.

3.4.2.2 Selection based on full text review

In the next step of the selection process, the full text of the remaining 923 articles was reviewed. Articles which could not be filtered by abstract and title only were assessed in detail with the help of inclusion and exclusion criteria (see Table 12 and Table 13).At this stage a further 336 articles were rejected. Before conducting the quality appraisal process, articles were accumulated to a single file in order to locate duplicates. Among the 587 articles remaining, 292 articles were eliminated which appeared more than once from different databases. The remaining 295 articles were subject to quality appraisal process using the criteria described in next section.

Table 12 Criteria for Article Selection during title or abstract and full paper review

	Selection Criteria	Rationale
Title	The article should include the terms/keywords related to risk management and new product development	This is to keep the focus of the search towards the review question
Language	The article should only be in English language	This is in view of the Language proficiency of the author
Time	The article should be published after 1980	Most of the work around risk management and new product development has been conducted after this date.
Paper Type	Empirical, theoretical/ conceptual, literature review, modeling/simulation	Panel Advice – to widen the review perspective
Methodology	Qualitative, quantitative and Mixed Methods approach	Panel Advice – to widen the review perspective

Table 13: Exclusion criteria during title or abstract and full paper review

	Exclusion Criteria	Rationale
Title	Any article which did not include the terms/keywords related to risk management and new product development were excluded.	This is to keep the focus of the search towards the review question
Language	Any article other than English language was discarded	This is in view of the Language proficiency of the author
Time	Any article published before 1980 was discarded	Most of the work around risk management and new product development has been conducted after this date.
Paper Type	Newspaper, general press articles, white papers, working papers, research reports	After panel advice, only peer reviewed journal and conference papers were selected
Methodology	All articles other than Qualitative, quantitative and Mixed Methods approach	Panel Advice – to widen the review perspective
Domain of literature	Natural science, Computer science and engineering, Engineering sciences such as chemical, electrical, petroleum, mechanical and similar other	
Industry Sector	Medical (except some case studies from pharmaceutical sector), political, public, education, agriculture, not for profit, non-corporate, financial product. Chemicals etc.	

3.4.2.3 Quality Appraisal

The final criteria applied in filtering the articles were "Quality Appraisal" used to finalize the selection of articles. The various elements used in the process can be seen in Table 14. Three main elements were assessed for each article: Theoretical contribution, Methodological and data analysis and finally overall contribution. Each paper was assessed against the criteria using a straightforward scoring system.

- Yes: the criteria is met(High = 3)

- Somewhat: the criteria is met to a reasonable degree (Medium = 2)
- The criteria is met to somewhat (Low = 1)
- No: criteria is not met at all (No=0)
- N/A: the criteria are not applicable for this paper.

The highest score an article can achieve is 9. Thus, to make sure that only high quality papers should be selected, minimum benchmark score selected was 6. All articles which achieve score less than 6 were discarded.

However, the process was not followed for all articles. It was found that the process was more suited to empirical papers compare to other types of articles i.e. conceptual, modelling/simulation and practitioners articles. All conceptual papers were lacking any form of empirical work. Also, practitioner articles were lacking any theoretical or empirical evidences. In this paper, out of 58 papers, 37 were empirical in nature and thus assessed with the help of quality appraisal process mentioned in Table 14. Remaining articles (conceptual, practitioners and modelling) were selected based on subjective decision and panel member's advice by seeing if they may help in building the argument. Example of quality appraisal papers can be seen in Table 15.

Table 14 Quality Appraisal

Criteria	Level				
	Absence(0)	Low(1)	Medium(2)	High(3)	N/A
Theoretical Contribution	Does not provide any information at all	Add little to the body of knowledge about relevant theories and literature	Contribution is of some significance (reasonable review of literature and awareness of major theories)	Significant Contribution Excellent review of prior literature, and strong theoretical bases is provided	The element is not applicable
Methodology/Data Analysis	Methodology and data collection methods not described	Provide little and ambiguous detail of data collection methods and methodology. Lacking important evidences and information	Provide reasonable amount of information on data collection methods and methodology adopted	Provide all necessary evidences on data collection methods and methodology adopted including internal and external validity, excerpt of questionnaire or surveys and limitations etc.	The element is not applicable
Contribution	There is no enough information to assess the contribution of the article	Weak relation between conclusion and theories, frameworks and data presented	Small contribution to the field.	Clear contribution to the field. Presents new concepts, ideas or findings and are consistent with existing literature	The criteria is not applicable

Table 15 Sample of Quality Appraisal

Reference	Criteria1: Theoretical Contribution	Criteria2: Methodology/ Data analysis	Criteria 3: Overall Contribution	Total score/ Decision
Title: Effect of risk management strategy on NPD performance Author: Mu et al. (2009)	Author provided Significant Contribution in term of excellent review of prior literature, and strong theoretical bases. Provided a theoretical framework (High=3)	Provide reasonable amount of information on data collection methods and methodology adopted (Medium=2)	Clear contribution to the field. Confirm the existing perception of RM processes with the help of large empirical data findings are consistent with existing literature (High=3)	8/9 (The article was accepted)
Title: Managing project uncertainty Author: De Meyer et al. (2002)	No theoretical basis was provided (Since the article was practitioner type so I assigned N/A as a score)	No methodology / data analysis was provided. No any empirical evidence is provided. (I scored it N/A due to its practitioner aspect)	Small contribution to the field. (Score=2)	(2/9) Apparently, the score is too low for article selection but it was selected based on subjective decision as it was providing useful evidence for justifying my review question

As a result of this process a total of 246 articles were rejected. Thus the final number of articles selected for the final review was 49. Further articles were included which were taken through cross referencing (n=3) and Ad-hoc selection (n=6). Total articles reviewed in this study were 58.

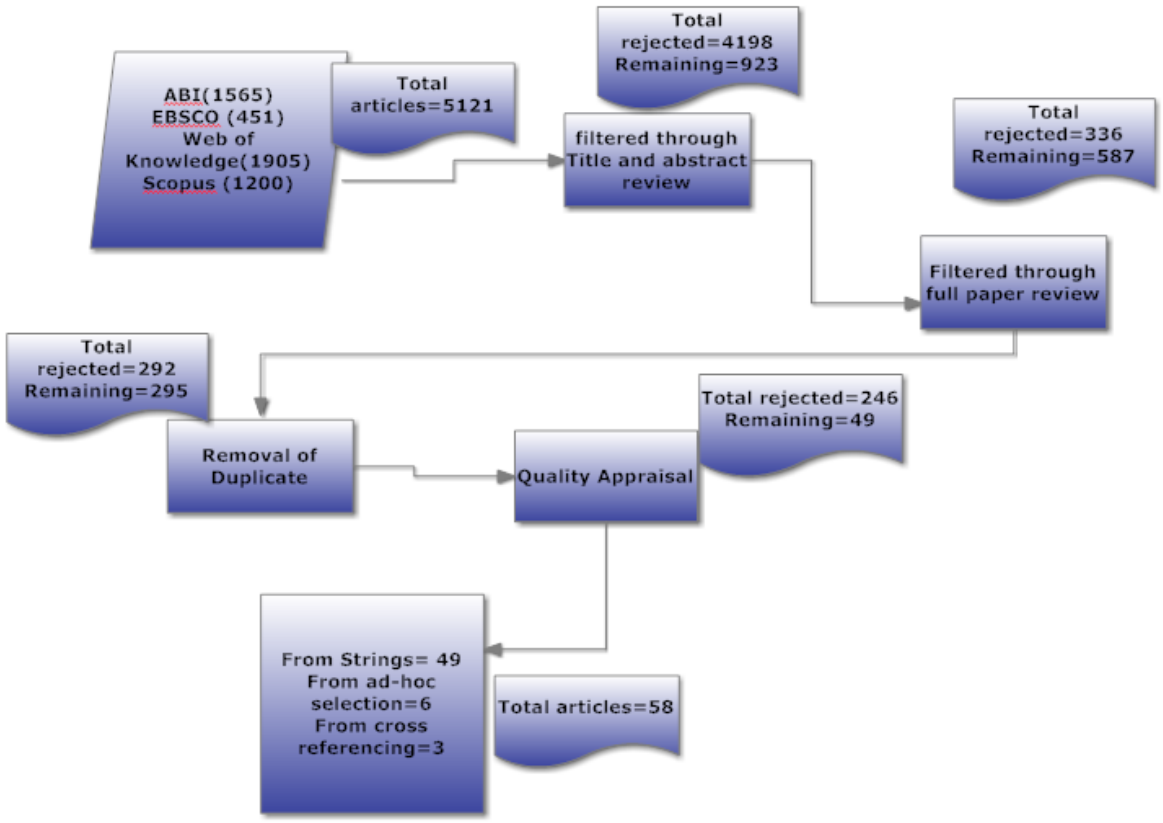

Figure 2 A Flow Chart of Selecting and Evaluating Studies

3.5 Extracting and Synthesizing Data

During the third phase of this systematic literature review, the data was extracted and synthesized. This phase comprised the following two stages: a) conducting data extraction; and b) conducting data synthesis.

3.5.1 Conducting Data Extraction

The following information is extracted from those articles that passed the quality appraisal check. Table 16 demonstrates the example of that.

Table 16 A Sample for Data Extraction Form

Title	4)Effect of risk management strategy on NPD performance
Article type	Empirical Supported by Literature, and empirically grounded
Focus	The article seeks to address the research gap by explaining and empirically testing how risk management strategy affects NPD.
Sample selection, size and characteristics	217 firms were surveyed
Industry type	Chinese cross industry
Country	China
Data collection methods	In-depth field interviews and surveys
Research Question	Effect of risk management strategy on NPD performance
NPD level	NA
NPD type	All
NPD risks	Market risks, technical risks, organizational risks
Main findings	Technological, organizational and marketing risk and their interactions have strong influence on NPD projects both individually and interactively.
Limitations	
Description of linkages with other studies	
Future research	

3.5.2 Conducting Data Synthesis

In the next step of the systematic review was to synthesize the main findings and results in a manner that illustrated the various aspects of risk management and new product development that are either covered or are not covered as yet by the researchers. Similarly, an attempt was made to answer the following questions: a) what sort of industry is not addressed? and b) what types of risks are addressed at different level of NPD process?

4 Descriptive Analysis of the literature

This section presents descriptive analysis of the findings extracted from the 58 papers identified. Descriptive findings are classified into different sub sections. These are scholarly articles covered in the review, yearly distribution of the articles, methodologies adopted, industrial sectors covered in the papers, articles distribution according to RM process, articles distribution according to various NPD stages, articles distribution according to different innovation types, articles distribution according to geographical characteristics and articles distribution according to topic wise classification.

4.1 Scholarly Articles Covered in the Review

A comprehensive and exhaustive search of the articles published from 1980 related to RM in NPD is performed. Articles included in the review are peer reviewed journal papers, proceedings of the conferences specialized in NPD and RM and a book chapter. Table 17 presents the name of the journal titles and their yearly contribution in the field of RM in NPD. It is interesting to note from the table that articles associated to RM in NPD are published into journals pertaining to multitudes of disciplines such as innovation, management, marketing and risks, indicating popularity and multi-disciplinary nature of the problem. A total of 58 articles from 42 journals and 2 conferences were reviewed. Journals that have published majority of the articles are International Journal of Physical Distribution and Logistics Management, Research Technology Management, Technovation and Journal of Engineering Design. Among these journals, some of them have greater impact on RM and NPD such as Risk analysis, Technovation, Research Technology Management, Journal of Product Innovation Management, Journal of Product and Brand Management, Journal of Engineering Design, International Journal of Risk Assessment and Measurement and International Journal of Product Development.

Table 17 List of Journal Articles

#	Journal Title	Years 2000-2012													Years 1970-1999												Total
		12	11	10	09	08	07	06	05	04	03	02	01	0	99	98	97	96	95	94	93	92	91	90	89	88	
1	The Academy of Management Journal												1														1
2	Asian Journal on Quality			1																							1
3	Association for Computing Machinery. Communications of the ACM															1											1
4	Benchmarking: An International Journal						1																				1
5	Computer Standards and Interfaces		1																								1
6	Computer & Industrial Engineering				1																						1
7	Creativity & Innovation Management									1																	1
8	Decision Sciences			1																							1
9	Engineering Management Journal																		1								1
10	Engineering Management Review											1															1
11	European Journal of Scientific Research			1																							1
12	IEEE Transactions on Engineering Management											1															1
13	IEEE Transactions on Software Engineering					1																					1
14	Industrial Management + Data Systems						1																				1
15	Industrial Marketing Management								1																		1
16	Integrated Manufacturing System												1														1
17	Intel Technology Journal						1																				1
		Year 2000-2012													Year 1970-1999												

		12	11	10	09	08	07	06	05	04	03	02	01	0	99	98	97	96	95	94	93	92	91	90	89	88	
18	International Conference on Engineering Design		1																								1
19	International Design Conference	1						1																			2
20	International Journal of Design					1																					1
21	International Journal of Physical Distribution and Logistics Management		1		1	1																					3
22	International Journal of Product Development				1																						1
23	International Journal of Production Economics	1																									1
24	The International Journal of Quality and Reliability Management					1	1																				2
25	International Journal of Technology Management				1																						1
26	Journal of Engineering and Technology Management			1																							1
27	International Journal of Risk Assessment and Management					1																					1
28	Journal of Business Research											1															1
29	Journal of Engineering Design		1			1																					2
30	The Journal of Product and Brand Management							1																			1
31	Journal of Product Innovation Management											1															1
32	Journal of Small Business and Enterprise Development								1																		1
33	Journal of Supply Chain Management		1						1																		2
34	The Journal of Systems and Software													1													1
35	Managing Global Transitions		1																								1
36	MIT Sloan Management Review							1				1															2
37	Proceedings of the 10th International Research Seminar on Supply Chain Risk Management			1																							1

38	International Design Engineering Technical Conferences and Computers and Information in Engineering Conference			1																								1
39	Product Management and Development					1																						1
40	Project Management Journal													1														1
41	R and D Management								1			1																2
42	Research Technology Management														1				1							1		3
43	Supply Chain Forum: An International Journal				1																							1
44	Technovation	1		1	1																							3
45	The Future of Design Methodology (Book)		1																									1
																												58

4.2 Yearly Distribution of the Articles

Figure 3 shows the yearly distribution of articles from 1988 since this year represents the first article written in the field of RM in NPD. Surprisingly, search in multitude of databases could not reveal any article from 1989 to 1993. Afterwards, not much has written on the field until 2000s and mostly articles appeared in a uniform way. Clearly, we can see a gradual increase in the number of articles in the next 10 years until 2011 and 2012 when a minor reduction in both years can be observed. However, this reduction was not due to the reduced interest of the researchers in the field but due to exclusion of number of article after quality assessment filtration.

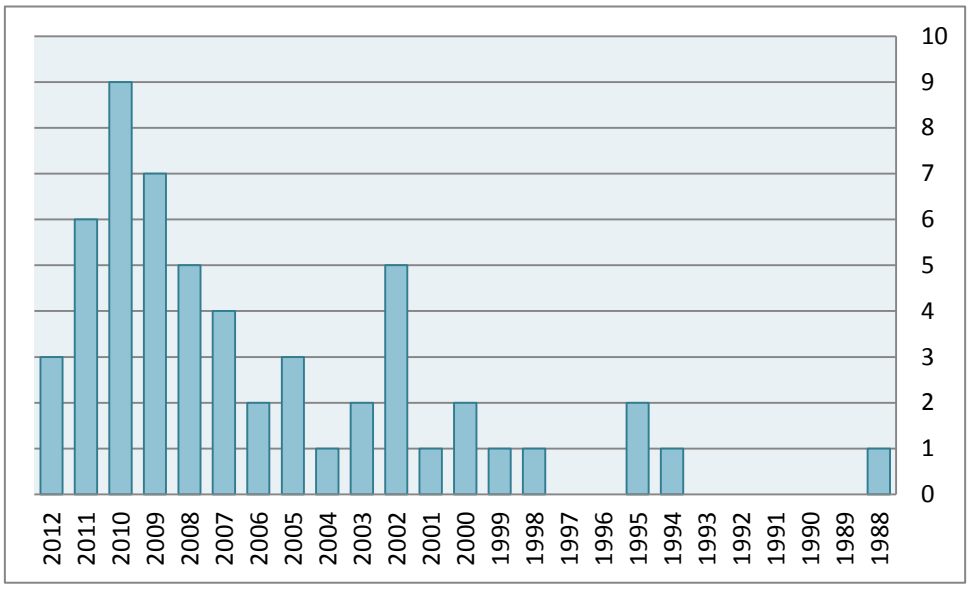

Figure 3 Yearly Distribution of Articles

4.3 Methodologies Adopted

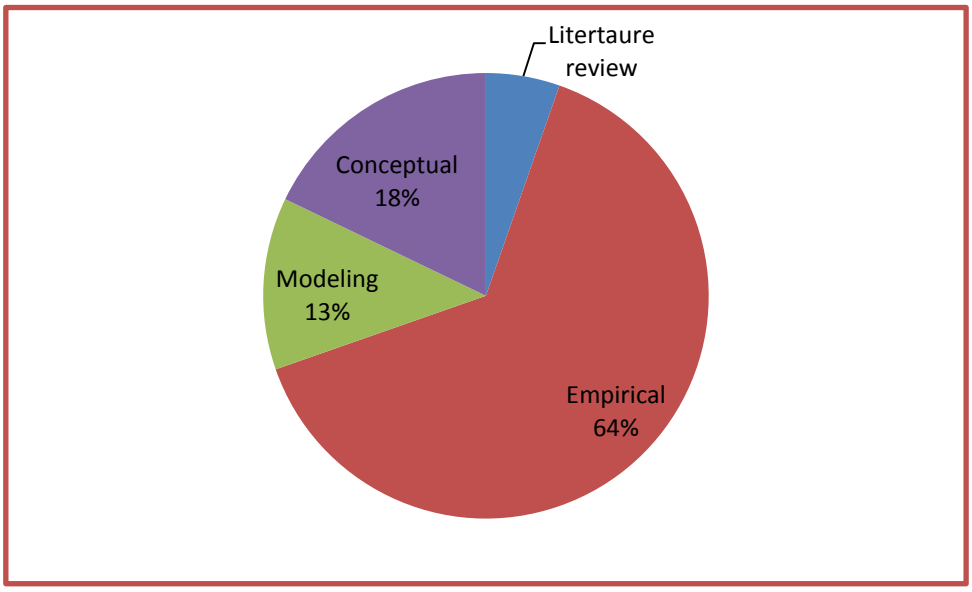

Figure 4 Methodologies Adopted (out of 58 articles)

Articles are classified according to their types, such as literature reviews, empirical studies, modelling and conceptual etc. Despite the fact that number of articles published in multitude of journals, we can see that most of research performed in this field is empirical i.e. 64 %. Conceptual articles consist of those articles that provide findings in the form of theoretical models and do not provide any empirical evidence for its validity. There are number of articles where research is presented conceptually i.e. about 18%.

Modelling involves articles which are based on mathematical models such as optimization models and simulation models. Clearly we can see that there is not much (13%) written in the field from modelling perspective.

Review papers are the type of articles that summarize the previous work done on this field generally or specifically. A number of articles which have presented review in term of RM approaches and strategies can be seen. However, we do not find any single review article which could have reviewed the literature in RM in NPD in a systematic manner.

4.4 Industrial Sectors Covered in Empirical Studies

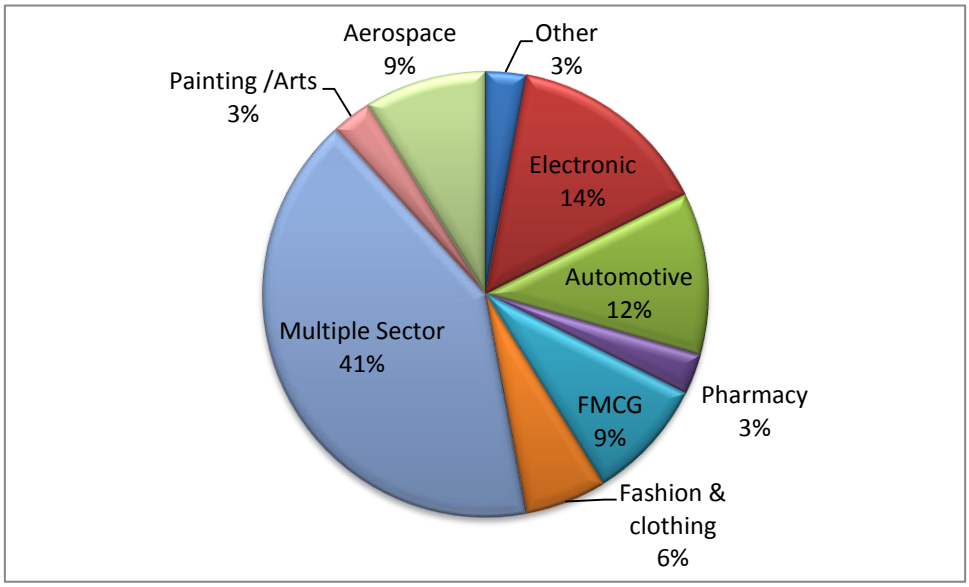

Figure 5 Industrial Sectors Covered in Case Studies (N=37)

Industrial case studies have always been an essential source of understanding problems and issues today' businesses facing. Without complete and thorough understanding of these issues, academic research would be of no use. There is voluminous amount of published works (64%, N=37) which focus on empirical analysis for RM process in NPD under different environment, industries and stages. Clearly we can see from Figure 5 that researchers have conducted cases on multitudes of sectors such as automotive, electronics and software, aerospace, pharmaceutical sector, FMCG, textile and clothing and multiple sectors. We can also see that majority of researchers (41%) have considered multiple sectors in their case studies. Also, most of empirical research was carried out in electronic (14%) & automotive (12%) industries.

We can conclude that mostly researchers performed cross industry research and that automotive sector is mostly influenced by risk and its associated issues due to its increasing percentage.

4.5 Articles Distribution According to RM Process

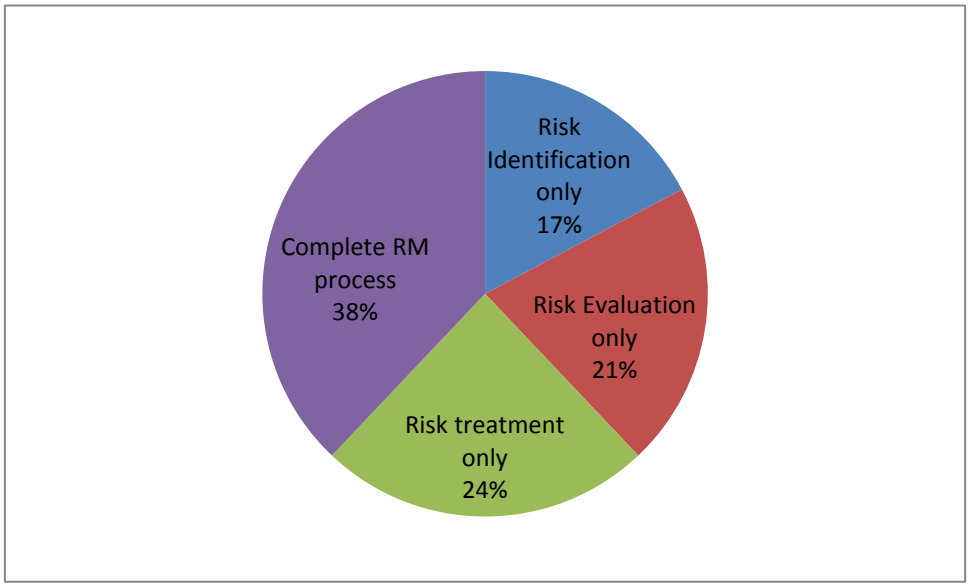

Figure 6 Articles Distribution According to RM Process (N=58)

Figure 6 shows the distribution of the articles according to general RM process. Though various different RM processes have been proposed in the literature, most of them follow a generic process (White 1995; Khan and Burnes, 2007): Risk identification, risk evaluation and risk treatment. Risk identification is the initial phase where risks are identified and their sources are diagnosed for treatment purpose. Once risks are identified, they must be then assessed as to their potential severity of loss and the probability of occurrence. Once the process of risk assessment is finished, appropriate risk management strategies can be adopted (Water, 2007). From the figure 6, we can see that most of the articles (38%) proposed or analysed a comprehensive RM process. Fig 6 also shows different phases of traditional RM and corresponding statistics. We can see that not much work has done on each of three phases as there are only few papers.

4.6 Articles Distribution According to NPD Stages

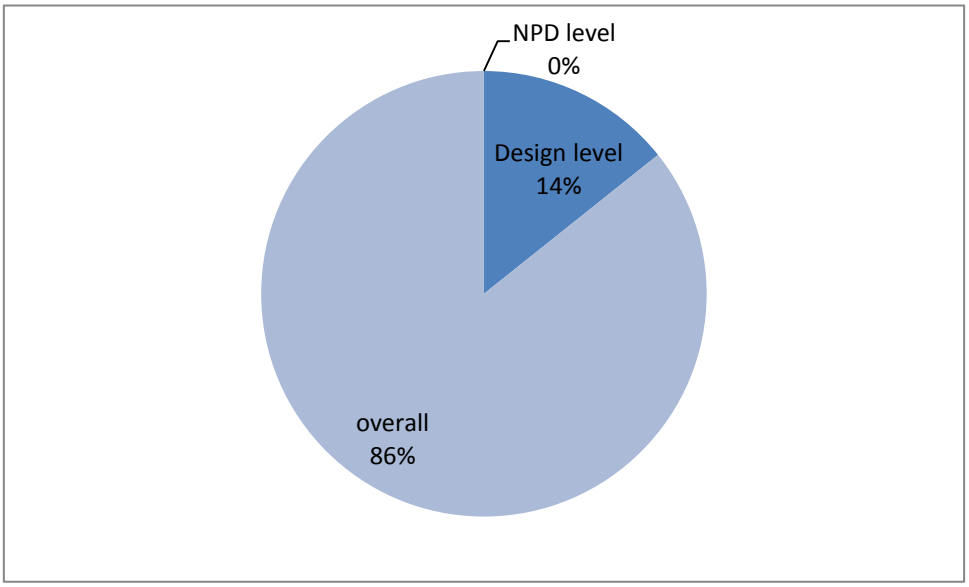

Figure 7: Articles Distribution According to NPD Stages (58 papers)

A NPD process is set of organized activities and tasks that transform set of input to a set of output (Unger, 2003). Generic NPD process consists of product planning, concept development, system level design, detail design, testing and refinement and production and ramp up (Ulrich et al., 2012). Figure 7 shows the classification of articles according to level of NPD process considered by researchers for RM purpose. We can see that majority of the articles (86%) did not limit their self to any of the particular phases of NPD process. Most of them considered overall NPD process during the investigation of RM activities. Very few articles (14%) have emphasized on the design phase for the analysis as can be seen in figure 7. The lack of research on other NPD phases or levels may also reveals the importance of design phase of NPD process in the RM process.

4.7 Articles Distribution According to Innovation Types

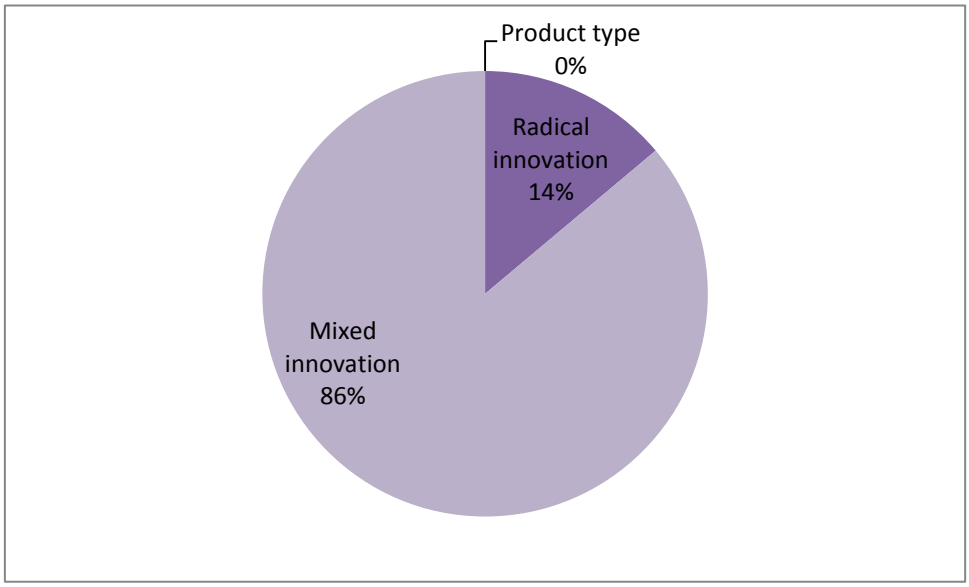

Figure 8 Articles Distribution According to Innovation Types (N=37 Empirical Papers only)

Another classification of the literature is performed according to innovation type (Figure 8). Overall, innovation can be classified into incremental innovation and radical innovation (Keizer et al., 2007). Both incremental and radical innovations are different in terms of scope, design, dependency, complexity and life cycles (Keizer et al., 2007). Incremental innovations are continuation of existing technology with minor adjustment for improvement. Conversely, radical innovation is major shift from existing technology or completely new innovation which never exists before (Keizer et al., 2007). Majority of the research (86%) did not try to distinguish types of innovations from their cases or data samples. It was very difficult to assess whether the type of products considered in any particular research associates with radical or incremental innovation. For example, in aerospace sector, the case study of Boeing 727 Dreamliner considered supply chain risks for NPD process (Tang et al., 2009). Majority of the spare parts used for designing the Boeing 727 were the continuation of existing technology i.e. incremental innovation. However, some parts are of radical innovation as they were never used before such as the use of composite material in designing jet body etc. Therefore, such articles were classified under mixed innovation title. Majority of the articles have

focused on either mixed innovation projects or intentionally ignore the fact to distinguish the type of products. Remaining (14%) articles specifically focused on radical innovation types and identified risks and proposed treatment strategies accordingly.

4.8 Geographical Characteristics

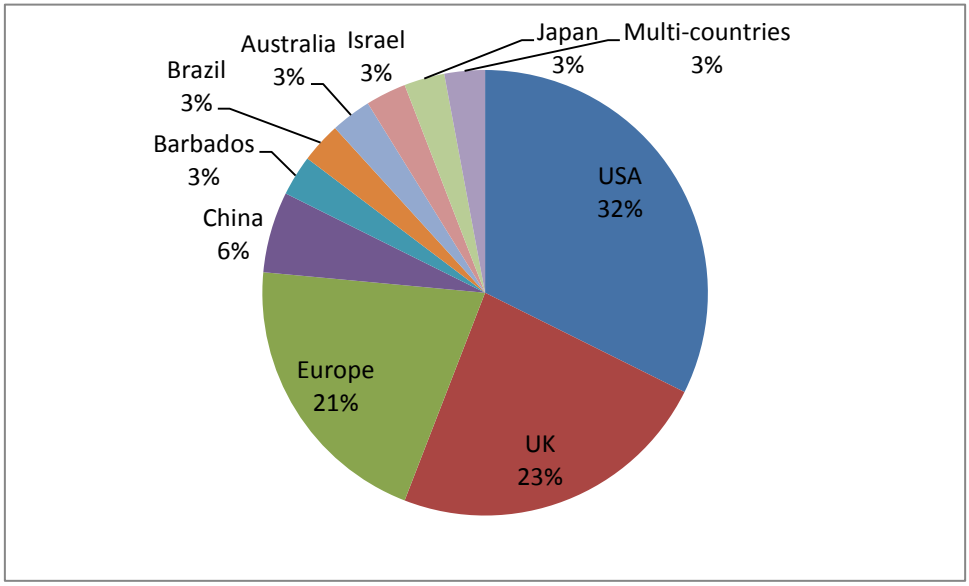

Figure 9 Geographical Characteristics (N=37)

Figure 9 shows the geographical characteristics for empirical case studies. It indicates that the majority of research conducted in the field of RM in NPD was in the US (65%) which is followed by UK (23%) and Europe (21%). If USA, UK and Europe group together, they constitute more than 76% articles. Remaining statistics indicate homogeneity of percentage among different regions such as 3% in Japan, Israel, Australia, Brazil and Barbados. USA and UK have dominated all other countries in term of NPD research. One of the main reasons would be the increased number research facilities exist there. Also, majority of the industry in terms of automotive and aerospace are situated in these countries. Surprisingly, despite its top position in industrial countries, I found 1 article where empirical analysis was conducted in Japan.

4.9 Topic Wise Classification

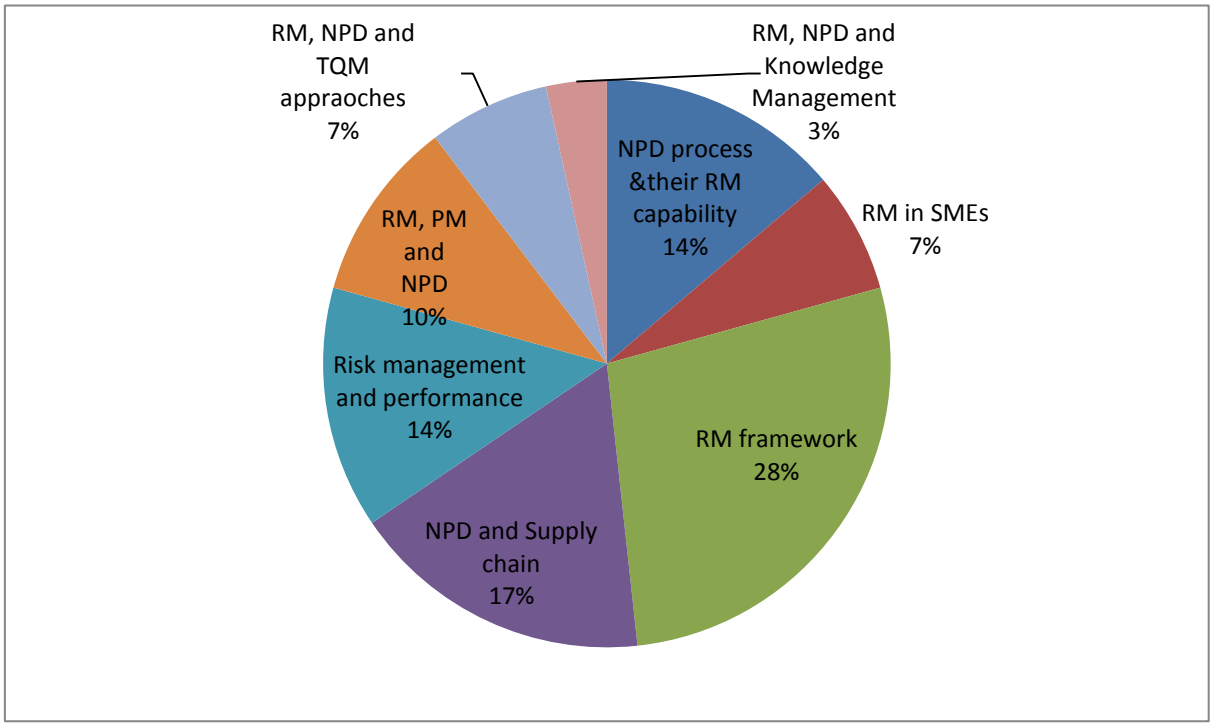

Figure 10 Topic Wise Classification (N=58)

Figure 10 shows the analysis of the distribution of 58 articles according to various subjects and issues. Exactly 28% of the articles proposed complete and comprehensive frameworks of RM. About 17 % of the articles integrated supply chain issues with NPD process. Some authors also investigated the phenomena of RM and its correlation with performance (14%). Another stream of research was carried on the intrinsic capability of RM of existing NPD processes (14%). Other prominent research areas are the integration of TQM tools with RM in NPD such as FMEA, QFD, and the use of knowledge management in managing risks and the integration of project management with NPD processes.

4.10 Summary

In this chapter, descriptive analysis of the findings from systematic review is presented. The initial two sections outline the journals characteristics and yearly distribution of the articles.

It emerges clearly from the Table 17 that articles selected for the review are associated to wider and diversified journals indicating popularity and multi-disciplinary nature of the problem.

Some of these journals are prominent academic journals such as Journal of Product Innovation Management while many of them belong to practitioner's type such as Technovation and Research Technology Management etc. Surprisingly, most of the research performed comes from prominent practitioner journals (about 20%). We can only see 1 article from the leading journal such as Journal of Product Innovation Management in this field. We can also see a gradual increase in the number of articles in the last decade which is making sense as much more disruptions and catastrophic events occurred during that period.

Further to that, it can be seen that research on risk management in NPD has been dominated by empirical studies.

Almost 75% of the empirical research was conducted in USA, UK and Europe. Regions such as Asia and Middle East are ignored. Most of the case studies were conducted on multitudes of sectors such as manufacturing, electronics and software, automotive, pharmaceutical sector, FMCG, textile and clothing and multiple sectors. Among all these sectors, automotive industry remained as highest rated research sector for researchers. USA and UK have dominated all other countries in term of NPD research. One of the main reasons would be the increased number research facilities exist there. Also, majority of the industry in terms of automotive and aerospace are situated in these countries. Surprisingly, despite its top position in industrial countries, I found 1 article where empirical analysis was conducted in Japan.

In terms of content analysed in the systematic review, various important aspects shown were articles classifications according to risk management process, according to NPD level, according to product or innovation types and types of risks associated to these innovations.

We can see that most of the articles 38 out of 58 articles proposed or analysed a comprehensive RM process. We can also see that not much work has done on each of three phases as there are only few papers.

This chapter also tries to show the management of risks during various levels of NPD process. Unfortunately, most of the researchers did not try to differentiate various level of NPD process during the investigation of NPD risks. Very few publications explored the types of risks at some specific level of NPD process. i.e. design level.

Another important critical aspect ignored by researchers intentionally or unintentionally was to distinguish among the types of NPD. Majority of the research did not try to distinguish types of innovations from their cases or data samples.

Finally, it was tried to classify the articles according to research focus and issues. Most of the articles proposed complete and comprehensive frameworks of risk management into their respective contexts and industrial sectors. Other prominent issues discussed in the articles are integration of supply chain issues with NPD process, risk management and its correlation with performance of NPD, intrinsic capability of risk management of existing NPD processes, integration of TQM tools with risk management in NPD such as FMEA, QFD, the use of knowledge management in managing risks and the integration of project management with NPD processes etc.

5 Thematic Findings

5.1 Introduction

This section of the paper discusses main findings reported in the literature of risk management (RM) in new product development (NPD). The main findings of the literature in this chapter are designed around the set of various main sub sections which help to structure the analysis. These subsections represent various themes developed from a trial and error process in order to classify the findings in the best possible manner.

In order to answer the review question, it was decided to classify the literature into some meaningful constructs. It was a challenging task to decide the way in which articles could be structured in the best possible manner. Initially, by seeing the publication date of articles, it was decided to perform a chronological review of the article. The first article which provided some insight on the NPD risk could be traced back to 1980s (See Chapter 4: Fig.3). After that, the field developed significantly in terms of research methods and industrial and regional contexts. However, the only benefit that could be achieved through chronological order was the understanding of gradual development of the field throughout the years which could assist in identifying various aspects of NPD risk management and their relationship with time factor. Since, all the articles reviewed were already filtered through 3 steps framework (see chapter 3 for further detail), which leaded toward the exclusion of number of article during 1980-2012. There, it was assumed that the benefit of chronological review could not make any sense in this situation.

Another way for determining the best structure was to review the existing literature review articles. There were number of literature reviews published in this field. These review papers were thoroughly investigated in order to see what type of classification schemes were used by the authors.

The earliest review in this field was conducted by Oehmen et al. (2006) where authors reviewed and discussed current methods employed in the area of RM in NPD. Author classified different approaches and methods along a general model of RM taken from existing literature. The generic steps of RM process and associated approaches were

i)Risk identification (identification by failure modes, checklists), ii) qualitative risk analysis (risk scenarios, 5 whys) iii) quantitative risk analysis (definition of general scales for impact likelihood and time, component of risk, risk matrix for likelihood and impact), iv) risk prioritization (Pareto analysis, top 10 risk ranking), monitoring of risks (numbers of risk development path, scenario based tracking of risks), aggregation of risks (total risk scenario). The major limitation of the review was that some approaches were also taken from outside the realm of NPD.

The next literature review was performed by Ahmed et al. (2007) where authors provided a review of techniques which can be used in the RM in NPD projects. Based on the Australia/New Zealand RM standards (Risk Management standard, 1999) , a generic framework for managing risks was used to classify and review the existing RM techniques. The generic RM process consisted of following steps: establishing the context, risk identification, risk assessment and treatment. Techniques proposed in establishing the contexts phase were project network diagrams, precedence diagramming method, generalized activity network, design structure matrices, functional modelling and process modelling. Techniques reviewed for risk identification phase were checklist, influence diagram, cause and effect diagram, failure mode and effect analysis, hazard and operability study, fault tree and event tree. The phase for risk quantification was classified into risk analysis and risk evaluation. Approaches for risk analysis were probability and impact grids, estimation of system reliability, fault tree analysis, event tree analysis, sensitivity analysis and simulation. Techniques for risk evaluation were decision tree analysis, portfolio management, and multiple criteria decision making method. Finally, for the phase of risk treatment, two types of strategies were proposed: reactive and proactive strategies. Both types of approaches could be used either to reduce the risk probability or impact reduction or transferring or avoiding the risks.

Next, in their brief literature review of 20 pre-selected articles, Segismundo and Miguel, (2008) presented a mapping of the literature on RM and classified them according to focus, approaches of the research and its respective area of application. The Authors argued that a tendency to use the case study compared to other approaches was observed. Also, 50% of the articles did not have a specific area of application.

Furthermore, it established that methods for project and risk management cannot be standardized for all types of projects but must be adapted in their scope and methodological uncertainty.

Finally, Oehmen et al. (2010b) reviewed the literature on RM in NPD according to the different phases of RM process proposed by ISO 31000 newly released international standards (ISO, 2009). The different phases under which literature classified were communication and consultation, establishing the context, risk identification, risk analysis, risk evaluation, risk treatment and monitoring and review. According to research, all phases of ISO 31000 RM process were addressed to varying degrees. Most of the articles addressed risk identification and analysis phases. Only few of them addressed the risk treatment strategies. The major limitation of the literature review was its focus towards the approaches and strategies used in different phases of RM process only. Author further argued that comprehensive case studies on the application of RM in NPD were missing.

Among 4 literature review articles published so far, 3 of them classified some of the literature on RM in NPD according to different phases of generic RM process. In this regard, they identified the tools and approaches needed for these different phases. Only 1 article classified the literature according to the focus and different issues of the research. Having in mind that classification of literature along different phases of RM process alone is not sufficient to answer the review question and may not classify the literature to the best possible manner, a comprehensive type of classification scheme was adopted. This classification scheme not only embedded the different phases of RM in it but also classify the literature according to some meaningful themes extracted from the literature. These useful themes were formed on trial and error basis. During trial and error process, various themes were added and removed until the optimal sets of themes formed. Although every effort was made to select optimal set of themes which could represent all 58 papers, literature could have been structured in many other different themes. This chapter reports the main findings of articles which are classified according to various themes constructed through a trial and error basis. These themes are

- Articles which investigate effect of RM process or activities on NPD performance or success (Section 5.2, 4 articles)

- Articles which discuss impact of supply chain risks on NPD (Section 5.3, 15 articles)
- Articles which focus on the RM capability of different NPD process (Section 5.4, 3 articles)
- Articles which consider comprehensive and formal RM processes (Section 5.5, 11 articles)
- Articles which do not consider complete RM process but consider some specific phase of RM process(Section 5.6, 19 articles)
- Articles which provide descriptive nature of analysis (Section 5.7, 2 articles).

Before presenting the main findings under each theme, a brief demonstration of trial and error process is presented with the help of examples for clarification.

Example 1: Effect of RM process or activities on NPD performance or success:

This theme consists of 4 articles which share two different common research agendas.

Table 18 Articles of different classification

Reference	Theme 1	Theme 2
(Raz et al., 2002)	Successful characteristics of RM activities	Effect of RM process on NPD performance
(Olechowski et al., 2012)	Successful characteristics of RM activities	Effect of RM process on NPD activities
Jiang and Klein, (2000)	Did not emphasize any on any specific RM characteristics	Effect of RM process on NPD activities
Mu et al. (2009)	Did not emphasize any on any specific RM characteristics	Effect of RM process on NPD activities

Initially, the first two papers are classified both under theme 1 " successful characteristics of RM processes" and theme 2 " Effect of RM process on NPD

activities" (See Table 18). Later on when two other papers related to theme 2 only are found, it is decided to classify all four articles under theme 2 which is common to all.

A more optimal classification can be to retain two themes as they are where articles (Raz et al., 2002; Olechowski et al., 2012) would have placed in theme 1 first and theme 2 later on. The only disadvantage in this situation is the repetition of same articles again. However, after consulting the situation with supervisor, it is decided not to classify the same articles in more than 1 theme. Consequently, the decision to classify the articles only once prevents to present the findings of articles in more reasonable way. Such situations are considered as one of main limitation of this trial and error process.

Example 2: Effect of Supply Chain Risks on NPD

In this theme, 15 articles are selected. The different research focuses for these 15 articles can be seen from Table 19.

Initially, when not all these 15 papers are synthesized together, they are classified under three separate themes. i.e. i) Supplier involvement risks in NPD process, ii) Conflicts during supplier involvement in NPD and iii) Impact of supply chain risks on NPD. After analysing all these three themes, it become obvious that all of these can further be classified under one common theme i.e. effect of supply chain risks on NPD. While majority of researchers are dealing supplier management issues and supply chain management separately, supplier related risks and uncertainties are still analysed and considered under the broader paradigm of supply chain risks (Tang et al., 2009). One benefit for synthesizing these 15 articles (previously classified under 3 themes) under one common theme is that it provides an exhaustive and comprehensive picture of different supply chain risks including supplier related issues, conflict issues and general supply chain risks which could further help in determining the causal relationship among them.

Table 19 Articles of different classification-2

Reference	Theme 1	
Lockstrom et al. (2011)	Supplier involvement in NPD	Supplier involvement risks in NPD process
Rebecca, (2001)	Supplier involvement in NPD	
Ragatz et al. (2002)	Supplier involvement in NPD	
Wognum et al. (2002)	Supplier involvement in NPD	
(Lee and Johnson, 2010)	Supplier involvement in NPD	
Zsidisin and Smith, (2005)	Early supplier involvement	
Chou and Chou, (2011)	Innovation outsourcing	
Chin, (2004)	Conflict management during supplier involvement	Conflicts during supplier involvement in NPD
Lam, (2005)	Conflict management during supplier involvement	
Kit et al. (2007)	Conflict management during supplier involvement	
(Khan et al., 2008)	Impact of product design on supply chain risks	Impact of supply chain risks on NPD
Khan and Creazza, (2009)	Impact of product design on supply chain risks	
Tang et al. (2009)	Impact of product design on supply chain risks	
Lin and Zhou, (2010)	Impact of product design on supply chain risks	
Oehmen et al. (2010a)	Impact of product design on supply chain risks	

Table 20 An overall view of rejected themes

#	Original Themes	Rejected Themes
1	Effect of RM process or Activities on NPD Performance or Success	Successful characteristics of RM process
2	Effect of Supply Chain Risks on NPD	Supplier involvement risks in NPD process Conflicts during supplier involvement in NPD Impact of supply chain risks on NPD
3	Risk Management and NPD processes	
4	Findings According to Different Constructs of RM Process	NPD decisions TQM and RM in NPD
5	Descriptive Nature of Studies	
6	Risk management processes for NPD process	

An overall view of rejected themes corresponding to each final theme is presented in Table 20. These main findings of each theme are reported in the coming subsections.

5.2 Effect of RM process or Activities on NPD Performance or Success

There are some research articles which focused on the empirical testing of the actual success rates of various types of RM practices or activities and their effect on NPD performance. The findings of this section help to determine how academicians, practitioners or researchers perceive RM effect on overall NPD performance. We only found limited studies which tried to explore such relationships. The findings of these are presented in a chronological way.

Jiang and Klein, (2000) were the first one who explored the relationship between risk and NPD project effectiveness with the help of surveys conducted on 86 project managers in the context of information system development projects. Authors found

that overall project effectiveness was impacted by different risk factors such as lack of clear role, conflict in team goal, lack of user support and lack of expertise. The different dimensions of project effectiveness considered in the study were ability to meet project goals, amount of work produced, quality of work produced, adherence to schedules, efficiency of operations, speed of operations and adherence to budgets. While results proved that overall project effectiveness was impacted by aforementioned risks, there was no any evidence which could answer what specific dimensions of project effectiveness was impacted more and which one not. The study was conducted in information system (IS) contexts, thus it is difficult to generalize the results.

Another study was conducted by Raz et al. (2002) where authors examined the extent of usage of specific RM practices and their impact on NPD projects success. The survey was conducted across 100 different types of multi sector NPD projects in Israel. Different RM practices such as risk identification, planning for uncertainty and probabilistic risk analysis were tested along various dimensions of NPD success. These dimensions were meeting technical specifications, meeting functional specifications, meeting schedule and meeting planned budget. It was found that only limited amount of NPD projects used any kind of RM practices. However, projects which used RM practices were able to meet schedule and budget goals only i.e. two dimensions of NPD project success. Authors did not find any evidence of RM practices and their impact on meeting technical and functional specifications.

The effect of RM on NPD performance was also analysed by Mu et al. (2009) in Chinese context with the help of data collected from 217 multi sector Chinese firms. Authors concluded that management of specific risk factors such as technological, organizational and marketing risk strongly influenced the NPD performance both individually and interactively. Despite the fact that data sample was large enough to validate the claim, NPD performance was not explicitly defined in the research. It was not clear what types of different NPD performance dimensions were strongly or weakly affected by the management of these risks.

Recently, Olechowski et al.(2012) studied 277 NPD projects from the aerospace and defence sector at USA and evaluated the impact of RM practices on NPD program performance. Compare to previous studies (Mu et al., 2009; Raz et al., 2002), this study

incorporated much larger sample of companies. With the help of literature review and based on the input from industrial experts, 38 variables constituting different RM activities were identified and measured along the four dimensions of NPD performance outcomes: program cost, schedule, and performance and customer satisfaction targets. A strong relationship between RM and overall program performance was observed. However, authors did not report any evidence for impact of RM activities on specific program performance dimensions. Also, the survey was conducted in aerospace and defence sector which might not allow generalization of results to other sectors.

The findings in this section revealed some interesting facts. It is clear that RM activities have positive influence or effect on NPD performance. However, the fact which was ignored by almost all authors was the impact of RM process or activities on specific dimensions of NPD program performance. Another limitation observed was the use of specific RM activities to assess their impact on NPD performance. No research was found which could have analysed the impact of overall RM performance on NPD projects.

5.3 Effect of Supply Chain Risks on NPD

Due to globalization and increasing customer demands, competition in businesses has tremendously increased. Such competition in the market creates a dynamic and turbulent environment where customers expect fast product delivery at cheap prices with better quality (Ulrich et al., 2008).This demand the need of essential involvement of various stakeholders in terms of suppliers, logistics providers and customers etc in various phases of NPD (Ahmadi et al., 1999; Oehmen et al., 2010; Sommer et al., 2008). Various articles reviewed in the systematic review discussed supply chain implications on NPD process and its associated risks. A chronological review is presented below.

There is a stream of research which discussed supplier related issues. As the NPD process is getting more and more complex, companies are outsourcing parts of their NPD process to suppliers (Thomas, 2009). With the help of case study conducted at 30 automotive firms which carrying out their manufacturing operations at China, Lockstrom et al. (2011) found that firms possessing highly rigid purchasing process, high product and process requirements, high expectations from their headquarters are

mostly facing issues during integration of suppliers into their NPD operations. Out of 30 cases, majority of firms found first two issues to large extent while 3 firms were influenced with the risk of high expectations from headquarters. Risks which complicated the buyer-supplier relationships stem from buyer side were lack of cross cultural management skills of expatriate managers; long feedback process leads to time constraint and lack of in house testing facilities at china resulting in longer inspection time. Risks originated from supplier side were lack of project and process management capabilities which also included basic know how and engineering capabilities, lack of quality and lack of effective communication. Since the study emphasized on local supplier integration and was conducted in Chinese context, findings might not be generalized.

Studies also began to investigate risks rise during buyer-supplier integration during NPD process which are uncontrollable in nature and associated to environment. Rebecca, (2001) explored two types of risks named as environmental risks and organizational risks. Environmental risks are logistical problems due to poor infrastructure both at national level and regional level, fiscal and tax distortions, difficulty in obtaining adequate financing, lack of effective 2nd and lower tier suppliers, exchange rate problems, high land and labour costs. Organizational risks include excessive bureaucracy causes long internal procedures inhibiting improvements in relationships, lack of effective communication in main functional departments associated to NPD. The study was investigated both from buyer and suppliers perspective and based on cases conducted at Brazilian Automotive industry. Both buyer and suppliers had difference of priorities on risks as buyer was concerned more about environmental risks while supplier's concern was inclined towards buyer's organizational risks.

With the help of large surveys conducted in 83 firms, Ragatz et al. (2002) listed various risks which inhibit the effective relationship between buyer and supplier during NPD process. These include resistance on sharing proprietary information relevant to the design from both parties, and a ‘‘not invented here’’ syndrome from buying companies. Unlike the study by (Rebecca et al., 2001) where author analysed incremental NPD only, this study focused on radical innovation NPD .

Another study which analysed both buyer and suppliers perspective on the risks was conducted by Wognum et al. (2002) where authors identified potential risks stem from buyer supplier collaboration during NPD process. By using case study approach in 3 Dutch firms, authors found that risk associated with suppliers were the lack of proactiveness in approaching clients, risks involved in selection and execution long term orders, lack of skills and knowledge about design and customer requirement, too little standardizations in executing activities allocated to more than one client, lack of experience. On the other hand, risks associated with buyer were supplier selection, decision making risk for those activities that require supplier involvement, organizational resistance and lack of communication means.

There are some articles which analysed the types of conflicts stem during buyer supplier collaboration. A conflict is referred to disagreement between both parties in terms of views, opinions and ideas during NPD process (Kit et al., 2007).

Based on a survey conducted in 193 supplier's premises, Chin, (2004) explored the relationship between conflict intensity and overall NPD performance. Author identified various NPD project factors which were potential candidates for influencing conflict intensity and its handling styles. These factors were product technical complexity, product certainty, task interdependence and relative power of supplier. Author did not find any significant relationship between conflict intensity and product complexity, task interdependence and supplier power. However, conflict intensity strongly impacted product certainty which means that higher the product specifications' clear to supplier, the less conflicts occurs between both parties. Two conflict handling styles were explored along these four product factors i.e. integrating and dominating styles. Product certainty, tasks interdependence and supplier power were positively impacted by integrating style. However, dominating style only effect product complexity and power of supplier.

Lam, (2005) identified 13 success factors for conflict management through extensive literature review and classified them into 4 main types: relationship management, conflict handling system, NPD process management and communication. With the help of case study conducted in electronic firm, author found that both suppliers and buyers had different focus and style for prioritizing these factors. Based on these factors, author

proposed a hierarchal conflict management framework. However, no empirical evidence was provided for applicability of framework.

The effect of supplier involvement in NPD and its related risks was also explored by Zsidisin and Smith, (2005) where authors focused on NPD with the integration of supplier as co-designer. According to single case study conducted in automotive sector, organization followed a systematic early supplier involvement (ESI) model for supplier selection. Authors presented various evidences which show how ESI in design process helped organization to reduce the supplier related risk. Some of risk sources reduced through ESI were excessive cost, legal liabilities, quality problem, supplier capacity constraint, extended product development time, inability to handle product design change and supplier organizational leadership issues. A major limitation in the study was it small sample size which limited the extent to which the claim of the study could be generalized.

Another study which discussed types of conflict and its management was conducted by Kit et al. (2007) where authors explored distribution of conflict along various phases of NPD and their corresponding drivers. With the help of literature review and case study, authors identified 16 sources of conflict and showed that conflict has a significant negative relationship with NPD performance in terms of product quality, and meeting of target development costs and delivery schedule. The study also assessed the impact of different conflict management styles. While authors found that cooperative styles which include integrating and obliging were effective in resolving conflicts, uncooperative styles which include dominating and avoiding appeared to be ineffective.

The essence of the study conducted by (Khan et al., 2008) explored impact of product design in managing supply chain uncertainties and threats. Authors investigated the RM practices adopted by single UK based clothing retailer during its recession period. According to authors, a systematic RM process was conducted to understand the main causes of risks and appropriate strategies. RM process consisted of three main steps: Risk identification, risk assessment and risk treatment. Among the critical steps, firm adopted supply chain sourcing policy i.e. bringing design back in house ad improvement in internal design capability. The study shows that these practices

significantly mitigated supply chain risks. The major limitation of the study was its small sample size and specific contexts.

Khan and Creazza, (2009) also investigated the issue of supply chain risk on product design by aiming to provide a roadmap that leads towards design centric business. Case study approach was used in three diversified manufacturing companies at Europe. Authors investigated various sources of supply chain risks associated to company NPD process. The most common risks with were lack of collaboration in the supply chain, lack of concurrent practices and lack of cross functional involvement in the product design process. To mitigate these risks, authors proposed design centric roadmap. The main limitation of the research was its absence of empirical evidence for proposed roadmap.

Tang et al. (2009) analysed the prominent case of Boeing 727 Dreamliner in order to identify supply chain risks which caused massive loss both financially and reputation wise. Boeing adopted unconventional methods for NPD process in terms of design, the development process and supply chain which were never used before in aerospace sector. Also, the project management team did not perform any formal RM process before or within the NPD process. It was reported that key risks which caused the delay of Boeing 727 innovation were technology risk, supply risk, process risk, management risk, labour risk, demand risk. With the help of literature review and extensive industrial experience, authors proposed mitigation strategies for these risks which include improving supply chain visibility, improving strategic supplier selection process and relationship, modifying the risk sharing contract, proactive management team, proactive labor relationship management and proactive customer relationship management. The major limitation of the study was the absence of any empirical evidence for the strategies authors recommended.

Lin and Zhou, (2010) examined the impact of product design changes on supply chain risks. To identify risks associated to product design changes, a multiple case study approach in 3 special purpose vehicles (SPV) supply chain was conducted. With the help of semi structured interviews, authors prepared a typology of risk. According to typology, risks are categorized into two main dimensions; internal risk and external risk dimensions. Internal risks comprised of research and development (R&D) risk,

production risk, planning risk, information risk and organizational risks. External risk consisted of supply risk, delivery risk and policy risk. The study indicated that both internal and external risks are influenced when design changes requests are generated. While authors established link between product design changes and supply chain risk, various limitations were observed. Likewise the previous studies, the findings were based on small sample size of three firms within a specific context of SPV sector at China.

Oehmen et al. (2010a) investigated how decisions in NPD influences supply chain risks. First, authors identified various dimensions of risks which originated during the different stages of NPD process. These risks are different forms of dependency on suppliers, increased complexity of supply chain and misaligned incentives of key stakeholders. After that, authors proposed a conceptual framework for integrating supply chain risks in NPD. The major limitation of the proposed framework was its lack of empirical validation. The framework was developed with the help of existing literature and prominent case studies on supply chain risks etc.

Another study which considered supplier related risks during NPD process was conducted by (Lee and Johnson, 2010) where authors analyse three distinct types of risks. These risks are performance risks, relational risks and knowledge appropriate risks. With the help of large scale survey conducted on 128 US based firms, the impact of these risks and two risk coping mechanism was assessed on NPD success. Results included the strong effect of both contractual mechanisms to overcome the three types of risks for those firms which were associated to short term alliances with suppliers and higher technological turbulences only. Conversely, for the companies having long term alliance with suppliers and associated to lower technological turbulence were not much affected with these governance mechanisms in safeguarding from three types of risks.

With the help of existing theories, Chou and Chou, (2011) highlighted risks associated to innovation outsourcing which were technological risks, market risks, business environment risks, R&D process risks, project size and management risks, customer risks, work force risks and outsourcing life cycle encountered risk factors. The research was conceptual based and lacking any type of empirical evidences to support their validity.

This section summarized the main findings from the articles associated to supply chain and its related risks. Interestingly out of 15, 9 papers emphasized on the supplier side issues and analysed the related risks which showed the significant importance of supplier related risks. Two authors' analysed conflicts which appear during the collaboration of NPD process with suppliers and assessed different conflict management mechanisms on various conflicts. Depending upon the situations and contexts, some mechanisms appeared to be effective for some conflicts. Only one research conducted by Zsidisin and Smith, (2005) analysed the implications of ESI during NPD process and presented its benefits in minimizing supplier side risk. Interestingly, we found two articles where the concept of ESI was not supported. Many authors adopted a comprehensive view of supply chain risks and provided typologies of risks. In this regard, most of the research provided conceptual frameworks and risk mitigation strategies. However, none of them provided any empirical evidence for their contributions. We also found 1 article which tried to analyse the extent to which different risk mitigation strategies were useful to cope with certain risks.

5.4 Risk Management and NPD processes

Another stream of research focused on the RM capabilities of NPD processes such as stage gate, spiral and waterfall models. According to Bassler et al. (2011), literature recognizes the different NPD processes as risk management structure which means that these NPD processes have intrinsic capability of managing risks. We found three articles which focused on RM capability of various NPD processes.

Unger and Eppinger, (2009) compared and contrasted waterfall, spiral and their hybrid approach in term of their management of risks. Authors discussed two dimensions of these NPD processes which were "iteration" (narrow iteration within phase to comprehensive iteration i.e. cross phase iteration) and review (from rigid review that are frequent with fixed requirement to flexible review less frequent with more flexibility). Due to its sequential nature, the stage gate NPD process mainly focuses on identifying uncertainties in system integration and understanding customer requirements. Narrow iterations make sure to meet actual performance requirement within and after each phase. In this way, stage gate is also capable of capturing technical risks. However, due to its lack of flexibility, the process is not recommended for dynamic environment. This

also shows that stage gate process is incapable of capturing competitor risks and supplier side risks. Unlike stage gate process, spiral process is more flexible and well suited regarding the uncertainty of customer requirement. Due to its nature of cross phase iterations, it can integrate stakeholder commitment and reviews throughout at any stage. Thus, the process is recommended for complex NPD projects.

Based on the two common characteristics of various NPD processes Unger and Eppinger, (2011) proposed a design method which help companies either to select or design a NPD process that best matches the risks associate to their process. Based on various case studies conducted at software, power generation, defence, automotive, aviation and communication sectors, authors argued that processes with rigid review and narrow iterations tended to be staged process (one side of the continuum of NPD processes) that manage mostly technical risk, while process with flexible review and comprehensive iterations are tended towards spiral process (other side of the continuum of NPD processes) that manage mostly market risk. The main principle behind the proposed methodology was that once risks are identified and assessed at firm, they should be assigned to planned iteration cycle and to a design review either within or across NPD processes. While the proposed methodology was implemented to a sample company, its results were still not known and thus lacking any empirical evidence.

Recently, Bassler et al. (2011) analysed the extent to which various different NPD processes in the extant literature address risks. In this regard, they analysed and compared four common NPD processes: spiral model, waterfall, lean for 6 sigma and lean product development. The risk management ability of these four NPD processes was analysed along the different phases of risk driven design process proposed by Oehmen et al. (2011). Author argued that four NPD processes only partially addressed different types of risks and had their own weaknesses and strengths. The comparison was performed theoretically and no any empirical evidences were provided to justify their claims.

From the findings, we can see that extant literature partially recognizes the NPD processes as a risk management structure. First two articles analysed the intrinsic capability of various NPD processes and compared them. One of them also provided a

design methodology which help firms to select or design best NPD process. The main limitation of these researches was absence of empirical evidences.

5.5 Risk Management Processes for NPD processes

During the formation of themes, a stream of research was found where researchers presented comprehensive risk management frameworks. Comprehensive risk management processes consists of a systematic procedure aiming to identify, assess and treat different types of risks and related issues in NPD process. Having in mind the fact, we classify only those articles under this section which describe or touches all these RM activities altogether.

A chronological review of such contributions is briefly analysed in the coming paragraphs.

In the context of RM process, one of the first researches was conducted by Coppendale, (1995) who posited that a formal process or procedure for risk management dramatically reduce the likelihood of unexpected issues and problems to NPD projects. Based on the extensive experience in the industry, author devised a RM process which was claimed to be successfully implemented on wide range of industrial sectors such as aerospace, defence, material manufacturing and consumer durables. The risk management process consisted of identification of risks, assessing the likelihood and potential impact of risks and finally development of risk management plan accordingly. Though author presented a step by step procedure for each of RM phases, there was no any empirical evidence which shows successful implementation of RM program.

Smith, (1999) showed the significance importance of RM process and its impact on NPD success. Author provided various principles and guidelines for a successful RM process. Author proposed a step by step RM process which appeared to be useful for many organizations. The process consisted of three phases: risk identification, risk assessment and risk control. The process was fully based on author's own extensive experience and lacking any supportive empirical evidence to validate its applicability.

Royer, (2000) argued about the essence of RM within manager of various NPD projects. According to author, unmanaged and unmitigated risks are one of the primary causes of project failures. Author differentiated the risks as recognizable risks and unmanaged

assumptions. Recognizable risks are easy to identify during project planning and engagement activities such as technological risks, organizational risks and marketing risks etc. Unmanaged assumptions are neither visible not apparent as risks thus more vulnerable to projects. These assumptions usually made at various phase of projects and introduced due to organizational culture, incorrect perceptions and unrealistic optimism. Author posited that such unmanaged assumptions since not treated as risk, so when appear wrong, create chaos and failures in the project. In addition to risk typology, author provided RM activities and subsequent steps which consisted of risk identification, risk classification and risk treatment. Due to its practitioner nature of research, author did not provide any theoretical or empirical justification for the RM activities and process.

Keizer et al. (2002) presented a case study of the risk diagnosing methodology (RDM) developed by Philips to identify and evaluate technological, organizational, and business risks in product innovation. In their research, authors reported the successful implementation of RDM methodology to one of world's largest company in FMCG when they suddenly faced a massive project failure. Three main phases of RDM methodology were risk identification, risk assessment and risk development and control. Risk identification phase consisted on activities like initial briefing between project manager and risk facilitator; kick off meeting among project manager, team and risk facilitator and individual interviewing of participants by risk facilitator. Risk assessment phase included the activities such as development of risk questionnaire by risk facilitator, answering of risk questionnaire by participants and constructing of risk profile by risk facilitator. Finally, the phase of risk response development and control contained preparing of risk management session by project manager and risk facilitator, risk management session among all stakeholders and finally execution of risk management plan. According to authors, the successful implementation of methodology influenced not only the decision making process of NPD projects but also assisted in identifying and quantifying various sources of risks. Despite the fact that RDM methodology appeared to be effective for the company, its practical implementation was not successfully reported such as what types of risks were identified, what approaches were used in various phases of risk management process.

Oehmen, (2005) unified various steps from existing RM frameworks related to different domains into an overall process framework. The framework consisted of three circles: inner, outer and integration circle. The inner circle starts when receives a trigger impulse from top management. This contains risk identification, risk assessment, mitigation measures and risk execution. The outer circle monitors the performance of RM process. The linking circle link the RM process to an overall enterprise approach. Like most of the research reviewed previously, author did not present any supportive empirical evidence for the validity of RM process.

Katsanis and Pitta, (2006) reported an application of RM to the NPD process in pharmaceutical company. The first decision, company made in designing the risk management effort was the timing of RM process. After considering the late versus early risk management efforts, the company agreed that the right time for conducting RM activities is at the design phase of NPD process i.e. at the beginning of the NPD process. Another important decision was the composition of risk management team. The risk management team was composed of several experts from different departments including experts in safety, risk management, regulatory affairs, medical affairs, medical communications, marketing, sales and legal department. Finally, the role and responsibilities of each team members were assigned according to their presence in the group either product developer or product commercializers. The case depicted an innovative application of RM process at pharmaceutical company. However, it was not reported in an explicit way. There was no any evidence which shows the implications of RM process on the net performance of company or on its product. Additionally, risk identification, quantification or treatment strategies were not reported as well.

Goodman et al. (2007) shed light on the RM process adopted by Intel to overcome and minimize the challenges faced due to increase in the complexities of NPD process. Author argued that deployment of the RM process tremendously improved the quality of NPD processes and reduced last minute fire fighting response to issues. Other benefits observed were increased communication across large platform development teams, accelerated product launches and quick responses to ecosystem changes. The RM process named as active RM was designed to tackle technology risk, platform integration risk and business risks. A 6 step RM process was adopted which consists of

RM planning, risk identification, risk evaluation and prioritization, risk quantification, risk response planning and risk tracking and control.

Dey et al. (2007) developed a RM framework for software development projects from developer's perspective for a public sector organization at Barbados. The different phases of risk management framework were analysing functional requirements, establishing scope of software development project and developing work breakdown structure, identify risky work package, identifying risky events, analysing risks, developing risk management plan and controlling risks. While, the RM process and its different phases were specifically designed for software projects and claimed to be successfully implemented, the study lacks any evidence which shows the successful implementation of process or its impact on overall NPD projects. More empirical analysis is required for its validation and generalization.

Very recently, Oehmen et al. (2011) proposed a risk driven process based on 4 principles which work as an intrinsic part of any NPD process. The first principle is i) creating transparency regarding design risk which identify and explore uncertainties in the design phase. The 2nd principle consists of making risk driven decisions where resources are allocated to top priority risks. The third principle is minimizing design uncertainty which include reduction of internal and external uncertainty. The fourth principle is creating resilience in the design system which includes creating responsive design system. The risk driven design process was fully theoretical based and lacking any empirical evidence to support its applicability in real life application.

Gosnik, (2011) tried to explore the factors which affect design uncertainties in any NPD projects and causes time delay. With the help of literature review and input from industry experts, authors formulated 2 main hypotheses for achieving research objective. The two hypotheses stated that undefined technical requirements leaded towards the design uncertainties of NPD and unclear project objectives play significant role in delaying NPD project. The study was conducted in 8 different NPD projects in the domestic appliance sector. The two highly cited impact factors which affect design uncertainties by respondents were lack of time for testing solutions and technical requirement for the products are not defined. The two factors were associated to technical requirements and thus confirmed the first main hypothesis. Similarly, factors

which strongly affect the time delay of NPD projects were unclear project objective, unrealistic time plan and limited authority of project manager and thus confirmed hypothesis 2 as well. Based on the factors identified from the data, author extended a traditional RM process by adding 4 key sub areas in the risk planning phase: project objective, organization of the project, project human resource and NPD process. While the proposed RM process was based on extant literature and practical data analysis, there was no any evidence which could provide its practical implications. Similarly, the findings from survey were limited to domestic appliance industry. Therefore, both impact factors causing design uncertainties and NPD project delay and extended risk management process need to be further investigated before generalizing to other contexts.

Wang et al. (2010) proposed a new RM framework which aligns project risk management with corporate strategy and performance measurement system to increase success rates of R&D projects. The framework integrates the balance scorecard (BSC) with quality function deployment (QFD) in a top down manner for managing the risks that have adverse effect on project outcomes and performance measures. The balance score card is used to define 4 perspectives of performance measures: finance, customer, internal business processes and learning and growth. Further to that, QFD is used to translate organizational measures to performance measure of NPD projects. Risks are identified during the initial phase where organizational performance measures are defined and translated to NPD project performance measures. After that, risks are assessed along each performance measures and action plan is devised to mitigate such risks. Author did not provide any evidence which showed the practical implementation of proposed framework.

This section has reviewed 11 articles which proposed risk management processes from various different contexts. Most of the proposed frameworks were consisted of three standard activities: risk identification, risk assessment or evaluation and risk treatment or control. Some of these processes were proposed by practitioners based on their extensive experience in the industry. However, they were lacking of any theoretical or empirical basis. Two frameworks were used in world top electronic and FMCG companies and findings were reported. Both confirmed its successful implementation

but did not discuss any explicit results. Another article presented specific risk management process for software based projects. Among all these risk management processes, risk driven design proposed by Oehmen et al. (2011) was the one which adopted different perspective from other in term of its implementation. All other RM processes work as external add-on on existing NPD processes, while risk driven design work as intrinsic part of NPD process.

5.6 Findings According to Different Constructs of RM Process

As we discussed in the introduction, majority of existing review articles classified literature according to generic risk management process. i.e. according to different phases of risk management process. Mostly, they classified NPD literature according to three standard phases of RM process which are risk identification, risk assessment or evaluation or risk treatment. A similar approach was adopted to address the articles. Key findings in the section are clustered into three main constructs of RM process i.e. risk identification, risk evaluation and risk treatment. This will help in developing understanding to what extent these constructs are used in NPD literature. The difference between the findings reported in this section and previous section has to be understood. Previous section only covered the articles which provided comprehensive RM processes i.e. articles which proposed and discussed at least three standard activities altogether. However, this section only covers those articles which cover RM activities partially.

5.6.1 Risk Identification

In any generic RM process, the goal of risk identification is to develop a detailed list of risks that have significance effect on the objectives (Oehmen et al., 2010). The risk identification process consists of several steps such as visualization of process, analysing the value creation, identification of risk causes and consequences and compilation of risk catalogue (Oehmen and Rebentisch, 2010), defining the overall process, dividing the process into a series of distinct, related operations, systematically considering the details of each operation, identifying the risks in each operation and their main features and describing the most significant risks in a register (Water, 2007).

In this section, we report the findings of those articles which fall under the general definition of risk identification as defined previously such as articles which provide

tools for risk identification or articles which provide risk typologies or taxonomies and articles which provide tools for categorizing risks.

Based on the interviews conducted by senior software managers from Finland, Hong Kong and USA, Keil et al. (1998) identified taxonomy of software project's risks and proposed a framework which can classify risks in appropriate way. Authors found numbers of risk factors which were viewed important by majority of managers during interviews and thus formed a universal set of risks or typology. Interestingly, most of these important risk factors perceived important which were not under the direct control of project managers. Based on this idea, authors proposed a risk categorization framework as 2x2 grids. One dimension of grid was perception of importance of risk amongst managers and other dimension was the perceived level of control. This 2X2 grid thus formed a 4 quadrant of risks which were named as customer mandate risks, scope and requirements, environment and execution. The main limitation of the study was absence of any empirical evidences and its formation on specific contexts which may disallow its generalization to other contexts.

De Meyer et al. (2002) showed that managers consistently fail to realize the different types of uncertainties and the fact that each of these uncertainties requires different mitigation approach. According to authors, one reason for such unawareness could be the traditional definition of the project scope which motivates managers to see the types of uncertainties at the outset of the project only. Based on their extensive experience in industry, authors identified the types of uncertainties which comprised of variation, foreseen uncertainty, unforeseen uncertainty and chaos. According to authors, to tackle with such type of uncertainties, managers should move from traditional project scope to dynamic scope which allow for the vision to change even in the middle of the project. Due to its practitioner nature, the research did not provide any empirical evidence.

Keizer et al. (2005) proposed a risk reference framework for diagnosing risks in technological breakthrough projects. With the help of 8 cases in one of world largest FMCG organization, 117 members were interviewed in order to gain an integral overview of technological, business and organizational risks. Taxonomies of risks were identified through literature review. Authors found that interviews elicited more risks than were recognized through literature review. Some of the risks very well documented

in the existing literature were consumer acceptance, competition, organization and project management risks. However, some risks not discussed in the literature were product family and brand positioning, commercial viability, product technology, manufacturing technology, supply chain and sourcing, trade customer acceptance, public acceptance and screening and appraisal. According to authors, the reason that these risks were not found in the existing literature was the fact that researchers investigated only projects which were already launched and released. On the basis of that, authors recommended that a distinction should be made on the risk factors associate to products that are in the initial phase versus the one which are already in the releasing phase. One of main limitations of the study was its conduction in one FMCG organization only. Also, analysis was made on the projects which were at feasibility phase only.

Millward and Lewis, (2005) analysed the barriers to new product development process in small manufacturing companies at UK. It was found that three main issues that inhibited the success of NPD process in small manufacturing companies were the influence of a dominant manager, focus on time and cost ahead of other key factors and failure to understand the importance of product design.

In their empirical case study on 5 small manufacturing companies at UK, Jerrard et al. (2008) identified a wide range of risks with the help of semi structured interviews undertaken by company personals. Interestingly, results highlight the very individual nature of risk perception among these companies. While, all the companies shared a number of core characteristics in terms of size, level of NPD process, serial innovation and location of the plant, only 2 of these specific risks were common to 3 or more companies, and only 6 common to 2 companies.

With the help of 8 cases conducted in single organization at FMCG sector, Keizer and Halman, (2009) investigated the types of risks associated to radical innovation projects. Taxonomy of risks was identified through literature review. By interviews with 32 senior managers responsible for radical innovation projects, author came with two main classifications of risks name as ambiguous risk and unambiguous risks. Risks clustered under the type of unambiguous risks were those which attained unanimously high scores from the respondents across all the eight projects. Conversely, risks where

respondents had disagreement upon their severity were classified under ambiguous risks. Three main risks associated to unambiguous were new product performance according to specification, reliability of suppliers and new product adoption by consumers. Authors argued that mostly risks considered as unambiguous are always on the agenda of project team due to their severe perception. Conversely, ambiguous risks are ignored. These risks constitute a set of issues every project team should seriously be aware of. Due to small sample size of 8 cases of radical innovation projects and FMCG context, the risks associated to ambiguous and unambiguous types may not be generalized.

There are few other articles which could be classified under the risk identification section. However, they were classified under other themes due to their significance relation with other themes (Lockstrom et al., 2011; Rebecca, 2001; Lin and Zhou, 2010; Chou and Chou, 2011; Ragatz et al., 2002).

In this section, 6 articles were reviewed which discussed and analysed some aspects of risk identification phase. Majority of them investigated the types of risks and proposed a kind of typology for various types of industrial sectors such as FMCG, software etc. One of the articles proposed a grid based risk categorization methodology. We found two articles which particularly focused on small firms and identified barriers and risks which inhibited effectiveness of their NPD processes. Finally, there was one article only which particularly investigated the risks associated to radical NPD. We do not find any article which provided any tools or approach for risk identification. Majority of articles presented risk typologies.

5.6.2 Risk Assessment or Evaluation

During risk assessment or evaluation phase, risks identified at previous stage are assessed and prioritized in term of their criticality. Furthermore, understanding is built about the relationship between risks and practices etc. (Water, 2007). The risk analysis process consists of various steps such as developing cause and effect networks for the identified risks, gathering data for the quantification of risk (likelihood and impact, or probability distribution), quantifying the risks and compiling the list of quantified risks (Water, 2007).

The first research that focused specifically on RM in NPD was the study by Abetti and Stuart, (1988) where authors proposed a unique way of examining risks by proposing three components of it: market, function and technology. Referring towards an old case study where 309 new products introduced by 63 small manufacturing firms in UK were examined, authors concluded that product risk increases with the degree of product newness and decrease with innovation uniqueness. Based on their extensive consulting and research experience, they further highlighted the implication of timings and the people who conduct RM activities. They argue that timing for risk evaluation is very important in a sense that too early risk evaluation may kill innovative ideas and too late risk evaluation may not be effective as product might already be launched. Author proposed a novel approach for risk evaluation based on the aforementioned dimensions of risks and the concept of product newness and innovation uniqueness. However, due to lack of any empirical evidence, its effectiveness may not be reliable as such. It should be noted that this early study was purely practitioner driven research thus lacking any theoretical or empirical evidence to support its arguments. However, the study has shown the importance of emerging phenomena of risk management in NPD influencing researchers and practitioners during 1980s.

Hise and Groth, (1995) found that NPD having strong association with external environments are more likely to succeed than those which are not. Effective assessment of external environmental risk increases the likelihood of success rate of product. Authors proposed a framework which consisted of different dimensions of environmental risks according to different scale rates. These dimensions were market risks, competition, and technology, political and social risks. Once the risk is evaluated according to these dimensions and mean score is achieved, it can be compared with net potential return. The effectiveness of such a framework could not be verified due to absence of any empirical evidences.

Browning et al. (2002) also proposed a risk value methodology which measures technical performance risks. Author provided the results for its practical implementation on uninhabited combat aerial vehicle. The hypothetical example showed its successful implementation and risks were found to be dramatically reduced. However, its practical findings need to be assessed in a large scale.

Dash,(2010) examined several risk assessment techniques currently used in the context of project management of NPD. These are the simplest approach and Function point analysis. The approaches were selected from the existing literature and no empirical evidence was provided for their applicability in industry.

Choi and Ahn, (2010) proposed a risk analysis model based on fuzzy theory and Markov process to determine the risk degrees of the risk factors occurring in product development processes. Fuzzy theory was incorporated in the model to determine impact value of risks while Markov chain was used to determine the likelihood of the risk. Both fuzzy theory and Markov chain integrated to assess the risks during the NPD process.

From the perspective of time-to- market risk, Wang and Lin, (2009) presented an overlapping process model integrating with Monte-Carlo simulation to assess the schedule risk of an R&D project. Several process design strategies were proposed in their paper to reduce the risk of late product launch.

This section so far reviewed 6 articles which proposed risk assessment or evaluation methodologies. Among them, one of researches proposed the methodology based on practitioner's perspective. The remaining 5 articles were purely theoretical and based on modelling and simulation. None of the methods were implemented on large scale industrial application or have empirical evidences for validity. Few of them were tested on hypothetical data sets only.

5.6.3 Risk Treatment Strategies

Risk control or treatment phase is one of crucial stages of RM process as it encompasses all activities that are concerned with the selection and execution of treatment measures for risks assessed and prioritized at previous level. It consists of several steps: analysis of management level and possible actions, analysis of impact of actions on event, cost benefit analysis of treatment options and decisions and compiling of treatment plan (Water, 2007).

We found number of articles which provided multitudes of risk mitigation strategies depending upon different contexts and nature of the problem.

Ogawa and Piller, (2006) proposed the idea of integrating customers into the innovation

process and introduced a new concept called ‘‘collective customer commitment’’. This concept reduces the risk of unmet customer needs. The research was presented according to practitioner's perspective thus lacking any theoretical and empirical evidences except authors' own experience.

With the help of case study conducted in 533 NPD projects in Japan, Song and Montoya-Weisss, (2001) analysed the moderating effect of technological uncertainty on NPD performance. Authors presented various risk treatment strategies such as cross-functional integration, marketing and technical project synergy, and proficiency in the marketing and technical development activities.

Also, Wang and Yang, (2012) showed that introducing managerial flexibility into R&D planning not only decrease technical and market risks but also increase potential market value. By using dynamic programming model, authors developed a flexibility planning methodology based on real option analysis to improve managerial flexibility for R&D projects. This methodology helps in identifying risks which occurs at every R&D stage and resolved them through a cascading option structure.

Park, (2010) proposed the management process which integrated both risks and performance measures in new product development (NPD). According to author, a successful NPD process requires both risk and performance to be measured in a systematic way. In the study, risk and performance factors were taken from the literature review. Authors concluded that both the timing of risk management and performance measure is important to the impact level of performance. The conceptual model provided were not explicitly defined and also lacking any empirical evidence to support the argument.

Davis, (2002) proposed a framework for the evaluation of the success rate of proposals for NPD. Author posited that most firms commonly use decision making though they are criticized for not properly accounting for uncertainty and project flexibility. The proposed framework categorizes the product portfolio categories into new ventures, new categories, new platforms and new product and assesses them according to three dimensions of risks: market risk, technical risk and user risk. The model which is based on net present value risk adjusted (NPVR) explicitly address critical risk factors in

traditional return on investment (ROI) models. The article focus was strictly practitioner based, thus lacking any theoretical and empirical evidence to support.

Segismundo and Miguel, (2008) examined the use of failure mode and effects analysis (FMEA) in 2 NPD projects conducted in automotive sector at Brazil. The tool was modified for the systemization of technical risk management and to optimize the decision making process in NPD. Results reported by authors include a reduction in number of projects and test planning loops as wells as reduced number of prototypes needed to approve product development. Additionally, a positive influence on the product development decision making process was observed.

Finally, Reich and Paz, (2008) developed an extension to resource quality function deployment (RQFD) based on simulations that supports diverse product development decisions. The method uses organization-specific information as well as market information and outputs the target product quality, the resources allocated to different tasks, and the risks involved in the project. The major limitation of the methodology is its empirical testing which is lacking.

In this section, we have reviewed 7 articles so far which provided different risk treatment strategies. These tools were ranging from collective customer commitment, knowledge management to introducing flexibility in the NPD process for managing better risks.

So far, there is only case study where Segismundo and Miguel, (2008) provided results for successful implementation of methodlog. Other papers which also provided some sorts of tools but could not seleted either due their generic nature such proposed within RM process contexts or article could be the candidate for other theme.

5.7 Descriptive Nature of Studies

Majority of the articles (56 out of 58) reviewed in the paper were fallen under the 1st part of the review question which stated how firm should manage risk? Conversely, we found only 2 articles which investigated the 2nd aspect of the review question i.e. how risk is being managed in the firm? In other words these studies try to investigate how risks are being managed in reality?

One of prominent research in this discipline was emphasized by Szwejczewski et al. (2008) where authors investigated 8 case studies in multiple sectors at UK. Authors highlighted that except one firm, all remaining firms conducted some form of risk assessment during NPD process. According to authors, the degree of formality of the process was differing for most of the companies. Majority of them do care about risk, however, their approach towards risk assessment was informal i.e. they tend not to follow any systematic or step by step risk management process. It was also found that most companies concerned about both technical and commercial risks. It was also confirmed by the case study that risk measurement process should be conducted at earliest stage of the NPD process. Most companies performed risk management at individual basis for each project. Most of the companies treated risk as a project management matter, to do with the effective management of tasks, not as something that might possible affect the outcome.

The second research in this section was conducted by Li et al., (2008) where authors investigated actual risk management activities and their correlations with the occurrence of risks associated to software components in 133 software projects with the help of survey conducted at Norway, Italy and Germany. Through literature review, a typology of risks associated to off the shelf (OTS) components and risk reduction activities were prepared and examined statistically from the respondents. The analysis of the results showed that 11 out of 13 risks in the typology occurred infrequently in practice. Similarly, authors did not find any statistical evidence of correlation between the risks cited highly frequent among the respondents and their corresponding risk reduction activities proposed in the literature.

Clearly, we can see that majority of the researchers focused on the aspect that how risk should be managed? Only two studies attempted to investigate the actual RM activities currently adopted by firms. Due to the fact that, both studies were conducted in UK and Europe in limited contexts i.e. manufacturing and software NPD projects, further in depth research is needed to investigate the phenomena in large scale.

5.8 Summary

In this chapter, the main findings from the 58 articles were reported according to the review question.

In order to report the findings from 58 articles for answering the 1st part, existing review papers in the field were extensively analysed. Based on the findings, it was decided to classify the literature according to main focus of the articles and according to main elements of generic RM process. Overall, the 56 articles were classified into 5 main themes which were i) effect of RM activities on NPD performance, ii) impact of supply chain risks on NPD performance, iii) article which proposed comprehensive RM processes, iv) articles which proposes either of the phases of RM process and finally v) articles discuss impact of risk management on NPD decisions. It was found that all these identified themes have been addressed in the literature to varying degrees.

The first main theme reviewed was" the effect of RM on NPD performance". There can be no doubt about the fact that RM process affect NPD performance as shown by all authors, but no evidence was found which could explicitly inform the effect of RM on any particular dimensions of NPD performance.

The majority of the articles analysed the impact of supply chain risks on NPD. Out of these articles, almost 60 % of the papers focused on supplier related risks and uncertainties. Remaining articles discussed all types of supply chain risks in their empirical analysis. Only one conceptual paper was found which provided a framework that incorporated supply chain risks in it.

Another stream of research focused on the RM capabilities of NPD process itself. It was found that extant literature recognizes the NPD processes as a risk management structure. Some of research analysed the intrinsic capability of NPD processes. One research also provided a structured comparison of different NPD processes.

This chapter also reviewed articles which proposed risk management processes from various different contexts. Most of the proposed frameworks were based on three standard activities of risk identification, risk assessment or evaluation and risk treatment or control. Some of these processes were proposed by practitioners based on their extensive experience in the industry. However, they were lacking of any theoretical or empirical basis. Among all these risk management processes, risk driven design proposed by Oehmen et al. (2011) was the one which adopted a different perspective from others in term of its implementation. All other RM processes work as external add-

on on existing NPD processes, while risk driven design work as intrinsic part of NPD process.

As we discussed in the introduction, the majority of existing review articles classified the literature according to generic risk management processes i.e. according to different phases of risk management process. About 30% of the articles provided various types of approaches and methodologies for these phases of risk management process. Interestingly, we did not find any article which proposes any methodology for risk identification except one article which proposes a way for categorizing risks. The majority of the articles proposed approaches for risk assessment and evaluation. Similarly, very few articles propose risk treatment strategies.

While attempting to address the last theme, we found two relevant articles which tried to analyse how risk is being managed in the firms. Clearly, we can see from the findings that most of the companies consider RM processes as a matter of project management activities. While the majority of the firms do care about risks, they do not adopt any formal risk management process. Due to the fact that, both studies were conducted in UK and Europe in limited contexts i.e. manufacturing and software NPD projects, further in depth research is needed to investigate the phenomena in large scale.

6 Discussion of Main findings and Possible Topics for Future Research

The review of approximately 3 decades of research into RM in NPD shows that there has not been much written in the field. Previously it was discussed that only limited articles were appeared from the researchers prior to 2000 (See chapter 4, Fig 3). Nevertheless, we can see an upsurge in research in the last 10 years. The extensive amount of rigorous research conducted to date enables us to synthesize the research findings according to two aspects of our main review question. These two aspects are i) what the literature tells how risks should be managed and ii) what it tells us how it is being managed practically. According to findings from previous chapter, there is a voluminous amount of research conducted on the aspect of how risk should be managed. Conversely, the other aspect" how risk is being managed practically" is not very well addressed in the literature as there were only few articles which reported some findings on this aspect.

In this chapter, a critical discussion on the findings of each theme is presented which could assist in identifying unexplored future work opportunities and form a basis for my PhD research question. The discussion is designed according to 6 main themes identified in previous chapter. Each of these themes is critically evaluated in order to see how they answer two different but interrelated aspects of the review question.

6.1 Theme 1: Effect of RM process or Activities on NPD Performance or Success

We found various evidences from theoretical literature that RM activities positively influence the NPD performance. These include contribution of RM directly to product and project success by creating the transparency regarding the risk situation (Oehmen et al., 2010b), minimizing the poorly defined technical requirements and unclear objective through RM which eventually lead to successful outcomes of the project and product (Gosnik, 2011), the successful impact of timing of risk management and performance measure on NPD performance (Park, 2010), alignment of risk management with organizational strategy and performance measures increases success rates of R&D projects (Wang et al., 2010), incorporation of managerial flexibility into R&D projects

which leads to an increase in potential market value (Wang and Yang, 2012), risk management as a solution to increasing complexity and decreasing robustness of products and processes etc. (Oehmen et al., 2006).

It can be seen that academicians perceive RM activities beneficial not only for project related matters but also assisting in minimizing the poorly defined technical requirements.

The review of the articles which specifically focused towards how risk is being managed in reality also confirmed that firms have realized the positive impact of RM process on overall NPD process. We do find some empirical evidences which indicate the effect of RM activities on overall NPD performance or success (Mu et al., 2009;Raz et al., 2002; James Jiang, 2000;Olechowski et al., 2012). With one except (Raz et al., 2002), no articles provide any evidence which shows the effect of RM activities on various dimensions of NPD performance. For example, Raz et al. (2002) found that NPD projects which use RM practices were able to meet schedule and budget goals i.e. only two dimensions of NPD success. Authors did not find any evidence between RM practices and their impact on the other 2 dimensions of NPD success which were technical and functional specifications.

It is clear from the above discussion that the extant literature does not provide any evidence on the effect of RM activities to some specific NPD performance dimensions such as RM effect on technical specification or functional specification.

It was also found that only a limited number of NPD projects use any kind of RM activities (Raz et al., 2002). The majority of firms which use RM program do not follow any formal or systematic procedure. Most of the firms conducted risk management activities as a project management (PM) matter which could enhance the effective management of tasks, not because it also affects overall outcome (Szwejczewski et al., 2008). It can also be assumed that most managers probably do not perceive RM activities as useful for NPD's technical and functional related issue. They just do it for the matter of project mangement. Apparently, such perception motivates managers not to use RM activities to a great extent.

The above discussion leads towards the following arguments. Extant literature provides some empirical evidences on the positive effect of RM activities on NPD performance. We do not have any enough evidence to judge what NPD success or performance dimensions affect. Similarly, it is clear that only limited number of firms use any type of RM process. Most of them just use RM for the matter of project management. Clearly, we can see that there is a requirement for in depth research which can describe and explain the different dimensions of NPD performance in an explicit way and assess the impact of risk management activities on each of these NPD dimensions.

Similarly, we only find one article that analyses the manager's perception about RM activities (Szwejczewski et al., 2008). The article states that most of the managers perform RM activities as a matter of project management which can assist in managing the task effectively. Further research is needed which can explore the phenomena of the perception of RM process or acivities among managers in different industrial contexts.

From the above discussion, the answer of two aspects of review question is now clear. It is clear that theoretically, researchers perceive RM activities' positive effect also in project related and technical matters, however, empirical evidences are lacking. . Thus, answers to both aspects of the review questions are not aligned with each other and require further investigation. Base on this discrepancy, I can propose following two main research questions.

RQ1: What various dimensions of NPD projects performance or success are influenced mostly by RM process or activities in practice?

RQ2: What are managers's perceptions of RM process or activities during NPD process? Are they fully aware of its potential benefits and implications?

6.2 Theme 2: Effect of Supply Chain Risks on NPD

We found a number of articles in the realm of NPD which discussed the impact of supply chain risks on NPD. It was observed that the majority of the articles (9 out of 15) talk about supplier related uncertainties.

In this regard, most studies investigate the types of risks stemming from the collaboration of buyer and supplier during the NPD process. Some authors provide the

typologies of risks in their research. Both incremental and radical innovations were considered during their analysis (Rebecca, 2001; Ragatz et al., 2002). By observing the nature of risks in both types of innovations, it can be concluded that risks associated to radical innovations are mostly design related. One research also analysis the concept of early supplier involvement (ESI) in NPD process and analysed the extent to which ESI help firms in managing supplier related risks. Finally, there are some articles which analyse the conflict established between buyer and supplier during NPD process. They identified different types of conflicts and conflict coping mechanisms.

It is clear that most of the articles focused towards the supplier related uncertainties. While, the main focus of the research was to identify different kinds of risks stemming during NPD process, risk treatment strategies are still lacking. Only 2 articles provided some sort of risk mitigation strategies and tested them empirically. Also, Zsidisin and Smith, (2005) reported the findings of successful implementation of ESI framework adopted.

Interestingly, most of the studies were conducted in automotive sector. We also found 1 article that tried to analyse the extent to which different risk mitigation strategies were useful to cope with certain risks in reality (Lee and Johnson, 2010).

Out of 9 remaining articles, research adopted a comprehensive view of supply chain risks and provided different typologies of risks through empirical case studies. They provided conceptual frameworks and risk mitigation strategies (Khan et al., 2008; Khan and Creazza, 2009; Tang et al., 2009). However, non of them provide any empirical evidene for their frameworks and strategies.

Also, Oehmen et al. (2010a) proposed a conceptual model of NPD process which has the intrinsic capability of capturing supply chain risks. However, it was not empirically tested.

Regarding the first part of our review question on how risk should be managed, we found quite a numbers of articles which show the nature of supply chain risks are very well understood by the researchers theoretically. This can be clear from the fact that researchers not only identified different typologies of risks but propose the number of risk treatment strategies and conceptual framework. On the other hand, we can also

conclude that nature of the supply chain risk is not very well addressed by the researchers in terms of its empirical testing. Regardless of the number of risk mitigation strategies and conceptual framework proposed by different authors, most of these are not empirically tested. Thus, we can say that evidences which show how companies are managing supply chain risks in practice are lacking. Also, we do not find any research which try to investigate how supply chain risks is being managed in reality.

In summary, we can say that supplier related risks and supply chain risks are very well presented in terms of their identification both. However, they are not very well addressed in term of risk mitigation strategies or frameworks as they are not very well tested.

From the above discussion and shortcomings observed in the theme, the following potential research gap can further be explored.

RQ3: How are supply chains risks being managed during NPD process?

6.3 Theme 3: Risk Management and NPD Processes

The third theme focused on the risk management capabilities of NPD processes. Extant literature recognizes the different NPD processes (such as spiral, Stage gate etc) as risk management structure. In other words, each of these NPD processes has intrinsic capability of managing various dimensions of NPD risks. So far, we found three articles which discussed the risk management capability of NPD process. According to the two main aspects of review question, we can claim that extant literature does recognizes the RM capability theoretically thus answering the first aspect in some sense and we do have theoretical evidences which analyse and compare the intrinsic capability of NPD process (Bassler et al., 2011; Unger and Eppinger, 2009; Unger and Eppinger, 2011). However, extant literature does not provide any strong empirical evidence where intrinsic capabilties of various NPD processes is assessed and compared . Thus the answer to the 2nd aspect of review question is that we do not have any evidence so far which state how risks are being managed practically with the help of NPD processes.

Based on this shortcoming, the following research oppurtunity is proposed.

RQ4: How different NPD processes manage risks?

RQ5: What are the manager's perception on risk management related performance of different NPD processes?

6.4 Theme 4: Risk Management Processes for NPD processes

During the formation of themes, a stream of research was found where researchers presented comprehensive risk management frameworks. A comprehensive risk management process consists of a systematic procedure aiming to identify, assess and treat different types of risks and related issues in NPD process. Having in mind the fact, we classify only those articles under this section which describe or touch all these RM activities altogether.

The risk management processes discussed in this theme are of three types. Some of these processes are proposed by practitioners based on their extensive industrial experience such as RM proposed by Coppendale, (1995), Smith, (1999) and Royer, (2000). All of these processes shared a common limitation that they were lacking both theoretical and empirical evidence. Although, every author claimed successful implementation for each of these processes, they do not provide any theoretical or empirical evidence for their claim.

There are number of RM processes which are proposed by academicians (Oehmen, 2005; Oehmen et al., 2011; Gosnik, 2011; Wang et al., 2010). All these processes shared a common limitation i.e. none of them were tested empirically. However, researchers do provide theoretical foundations for each of these RM processes.

Finally, there are some RM processes which were successfully implemented in different contexts (Keizer et al., 2002; Goodman et al., 2007; Katsanis and Pitta, 2006). These processes also shared limitation that no theoretical evidence was provided. However, the implementation of these RM processes resulted successfuly and benefits were realized.

While, we find a number of articles which describe how risk management should be performed, we just find 3 cases where successful implementation of RM process is reported. Although, these cases were claimed to be successfully implemented in some sense, no theoretical justification is provided.

Various implications can be made from the above disscussion. First, a number of RM processes have been proposed in the realm of NPD. Most of them are lacking either theoretical, or empirical foundations or both. Among all these RM processes, risk driven design process proposed by Oehmen et al. (2011) adopted different perspective from others in term of its implementation. While risk driven design work is an intrinsic part of NPD process, all other RM processes work as an external add-on on existing NPD processes. Another implication is that there is no any evidence observed which can highlight the issue regarding what existing RM processes are being used in the industry. It appears there is no single best RM process existing which could solve the issue of every company. So far we do not find any evidence which shows any theoretical or empirical comparison on the performance of different RM processes. Similarly, there are only limited numbers of articles that identify successful characteristics of risk management processes (Raz et al., 2002; Olechowski et al., 2012). However, there are several limitations in these studies. First, these studies were conducted in specific contexts in terms of both industry and region i.e. aerospace and defence, Israel and USA. Second, both studies selected specific RM characteristics for their analysis. They do not consider comprehensive RM process. Hence, we can conclude that more research is needed to understand different characteristics of RM process. Based on this discussion, the following future research opportunity is proposed.

RQ6: What characteristics of RM process are successful in terms of impacting NPD project success?

RQ7: What types of RM frameworks are used by companies during NPD?

RQ8: What are the managers' perceptions on the performance of various RM process?

6.5 Theme 5: Findings According to Different Constructs of RM Process

In the previous chapter, we have reviewed four literature review articles. The objective of reviewing these articles was twofold. First, to gain an understanding about the literature classification schemes used by authors, second to compare and contrast the

main findings with the findings of systematic review. Some interesting facts are presented below.

Three out of four articles classified literature according to generic RM process i.e. literature was classified according to risk identification, risk assessment and risk treatment phases. In this regard, the tools and approaches used within each stage were reviewed. One of the main limitations of these articles was that tools and techniques reviewed were not only taken from the NPD realm but other realms were also used. The only article which focused specifically towards the NPD realm was Oehmen et al, (2010b) where authors classifed the NPD literature according to ISO 31000 RM framework.

Among the findings of these existing literature reviews, Segismundo and Miguel, (2008) found an increase in the number of case studies. However, later on according to Oehmen et al. (2010b) findings, the case study apsect of research in RM in NPD is significantly missing. Apparently, both findings contradicted each other. The findings of systematic review confirmed the notion of Oehmen et al. (2010b) as it is found that very few articles adopted case studies approach in the field.

According to Oehmen et al. (2010b), most articles covered risk identification and risk evaluation phases only and treatment strategies were significantly missing. A quick overview of our findings in regard to these three phases can be seen in Appendix B.

Clearly we can see that only a limited number of articles addressed risk assessment phase. i.e. only 6 articles which described some form of approaches or tools to evaluate or assess risks. We can also see other articles which address the risk assessment phase. However, such articles were mostly the one which provide a comprehensive RM process. Also, the tools or approaches proposed in such articles are mostly taken from outside the realm of NPD.Therefore, such articles were not considered under the risk evaluation phases.The number of articles which address the risk identification phase are more than those addresing risk evaluation phase.i.e. 12 articles. However, most of these articles provided risk typolgies and classification only. We found only 1 article which presented a tool for categorizing risks. The figure of 12 may not be consitent with the figure written in thematic chapter 5 section due to the fact that there are a few other articles which could be classified under the risk identification section. However, they

were classified under other themes due to their significance relation with other themes. Examples of these papers are Lockstrom et al.(2011) , Rebecca, (2001), Lin and Zhou, (2010) Chou and Chou, (2011) and Ragatz et al. (2002).

It can also be seen that not many articles address risk treatment strategies. Our findings partially confirmed the view of Oehmen et al. (2010b) that very limited articles provided any kind of treatment strategies. Conversly, we do not find many articles for risk identification in terms of tools and aroaches as well which contradict their findings.

From the above discussion, it is found that all phases of RM process addressed in the NPD literature to very low extent. Majority of tools and approaches adopted or proposed by researches for risk identification and risk treatment phases were taken from other realms. Very few of them tested in the context of NPD. Apparently, all these shortcomings or gaps are potential candidate of future research.

RQ 9: What tools and approaches for different phases of RM processes are being used in industry?

6.6 Theme 6: Descriptive Nature of Studies

Clearly, we can see that majority of the researchers focused on the aspect of how risk should be managed? Only two studies attempted to investigate the actual RM activities currently adopted by firms. Due to the fact that, both studies were conducted in UK and Europe in limited contexts i.e. manufacturing and software NPD projects, further in depth research is needed to investigate the phenomena in large scale.

7 Conclusion

In this thesis, I conducted a systematic review on the field of risk management (RM) in new product development (NPD) by asking the review question "How are risks managed in new product development (NPD) process".

For the matter of simplicity, the review question was divided into two parts. The first part inquires how risk should be managed. This question requires an overview of the studies which investigate and proposes various solutions for managing risks. These studies consist of research proposed by both academicians and practitioners. Mostly such research consists of theoretical research which was sometime supported by empirical evidences and sometimes not. The second part of review question is how firms are managing risks in practice? This question requires an overview of the studies which investigate the ways firms are adopting in managing risk. While, there has been a lot written how risk should be managed, there are very few articles which investigate how risk is being managed by the firms.

There is voluminous amount of research reviewed in the paper which answers how risk should be managed. The overall research articles were classified into different meaningful themes. These themes should not be regarded as optimal one as literature could have been structured in many different themes. However, every effort was made to select best the possible set of themes which could represent all research articles. Each of these themes is critically evaluated in order to see how they answer two different but interrelated aspects of the review question.

The first part of the review question mainly covers the theoretical aspect of the review and those empirical papers which have presented theoretical model and then its practical implementation. Within each of identified themes, we found enough evidences which answers the question regarding how risk should be managed.

The 2nd part of the review question covers only those articles which investigate how companies are managing risks in practice. In this regard, we also consider some theoretical articles which have provided empirical analysis of their respective methodologies. Unlike the first part of review question which inquires how risk should be managed, very few researches are conducted in the 2nd part of review question.

In conclusion, it is found that there has been written a lot theoretically in the field of risk management in new product development. Extant literature provides a multitude of evidences on how risk should be managed. However, the area "how risk is being managed" is not explored to great extent. While the comparison was made in the discussion section under each theme, it is found that both aspects of review questions are not aligned with each other.

7.1 Limitations

This thesis is limited in several important aspects: First, this cannot be regarded as complete or comprehensive literature review in the field of risk management in new product development, although every effort has been made to include the articles relevant to review question.

The themes selected for classification of articles cannot be regarded as the best one as many articles could have been structured in many different themes.

7.2 Reflection and Learning Points

Since it was my first experience to write a systematic review, I found many learning opportunities throughout the process. In terms of content, one of the challenging tasks was the selection of optimal set of themes for 58 articles. During the trial and error process, many different themes were added, deleted and modified. It helps me in creating understanding about the pros and cons of adding, deleting and modifying the themes. Another learning opportunity was the synthesizing of main findings into some useful manner which can create potential research gap. This exercise provided me an insight and deep understanding of the overall content.

Furthermore, I also find the process of article selection very useful. Thousands of articles were filtered according to different steps of quality assessment framework in order to reach the amount of 58. Also, the process of extracting the data from the articles was another leaning opportunity.

7.3 Contribution towards Theory

One of the main contributions of the thesis towards theory is that it identified discrepancies among theoretical knowledge and empirical knowledge. Existing

literature provides various theoretical evidences which shed light on the different aspects of risk management in NPD. However, no in depth investigation is made so far which tries to bridge the gap between empirical and theoretical knowledge. Some of the prominent aspects identified where both theory and practice are misaligned are the effect of RM activities on NPD performance and dimensions and successful characteristics of RM processes.

7.4 Contribution towards Practice

On one side, bridging the gap between theory and practice contribute towards the theoretical knowledge, on the other side, it also provide an insight of what practitioners are doing in reality in managing the risks. This leads towards the identification of more practical research opportunities which will eventually help firms in managing their risk related issues.

References

Abetti, P. A. and Stuart, R. W. (1988), "Evaluating New Product Risk", Research Technology Management, Vol.31, No.3, pp. 40-43

Ahmadi, R. and Wang, R. H. (1999), "Managing development risk in product design processes", Operations Research, Vol.47, No. 2, pp.235-246.

Ahmed, A., Kayis, B. and Amornsawadwatana, S. (2007), "A review of techniques for risk management in projects", Benchmarking: An International Journal, Vol.14, No.1, pp. 22-36.

Bassler, D. (2011), Risk driven design, Integrating risk management as an intrinsic part of product development. MS. Thesis. Cambridge, USA: Massachusetts Institute of Technology.

Bassler, D., Oehmen, J, Seering, W. P., Ben-Daya, M. (2011), "A comparison of the integration of risk management principles in product development approaches", In: International Conference On Engineering Design, ICED. Copenhagen, Denmark.

Bernstein, P. (1996), Against the Gods: The Remarkable Story of Risk, Wiley, Chichester.

Bhuiyan, N. and Thomson, V. (2010), "A framework for NPD processes under uncertainty", Engineering Management Journal,Vol. 22, No.2, pp.27-35.

Boehm, B., Bose, P. (1991)," A collaborative spiral software process model based on theory" In: Software Process, Reston, VA, USA, pp. 59-68.

Browning, R. R., Deyst, J. J. and Eppinger, S. D. (2003), "Adding value in product development by creating information and reducing risk", Engineering Management, IEEE transactions, Vol. 49, No.4, pp. 443-458.

Browning, T. R., (1999), "Sources of schedule risk in complex system development", Systems Engineering, Vol.2, No.3, pp. 129-142.

Chin, P. (2004), "Project factors influencing conflict intensity and handling styles in collaborative NPD", Creativity and Innovation Management, Vol. 13**,** No.1, pp. 52-62.

Choi, H. and Ahn, J. (2010), "Risk analysis models and risk degree determination in new product development: A case study", Journal of Engineering and Technology Management, Vol.27, No.1/2, pp.110-124.

Chou, D. C. and Chou, A. Y. (2011), "Innovation outsourcing: Risks and quality issues", Computer Standards and Interfaces, Vol.33, No.3, pp. 350-356

Cooper, L. P. (2003), "A research agenda to reduce risk in new product development through knowledge management: A practitioner perspective", Journal of Engineering and Technology Management, Vol. 20, No.1, pp. 117-140.

Coppendale, J. (1995), "Manage risk in product and process development and avoid unpleasant surprises", Engineering Management Journal, Vol. 5, No. 1, pp. 35-38

Dash, R. (2010), "Risk assessment techniques for software development", European Journal of Scientific Research,Vol. 42, No.4, pp. 629-636.

Davis, C. R. (2002), "Calculated risk: A framework for evaluating product development", MIT Sloan Management Review, 43, No.4, pp. 71-77.

De Meyer, A., Loch, C. H. and Pich, M. T. (2002)," Managing project uncertainty: From variation to chaos", Engineering Management Review, Vol.30, No.3, pp.60-67.

Dey, P. K., Kinch, J. and Ogunlana, S. O. (2007), "Managing risk in software development projects: a case study", Industrial Management + Data Systems, Vol. 107, No.2, pp. 284-303.

DoD (2006): Risk Management Guide for DoD Acquisition. 6th Aufl. Washington, D.C.: United States Department of Defence, Office of the Secretary of Defence.

GAO (2011): Defence Acquisitions - Managing Risk to Achieve Better Outcomes (GAO-10-374T). Washington, D.C., United States Government Accountability Office.

Goodman, A., Hinman, E. J., Russell, D. and Sama-Rubio, K. (2007), "Managing product development risk", Intel Technology Journal,Vol. 11, No.2, pp.105-114.

Gosnik, D. (2011), "Extended Model of Managing Risk in New Product Development Projects", Managing Global Transitions, Vol.9, No.1, pp. 15-37

Graham, D. (1989), "Incremental development: Review of non monolithic life-cycle development models", Information and Software Technology, Vol.31, No.1, pp. 7-20.

Guo, Y. (2012), "Product Innovation Risk Management based on Bayesian Decision Theory", Advances in Management and Applied Economics,Vol. 2, No.1, pp. 43-54

Hall, E. (1998): Managing Risk - Methods for Software Systems Development. Reading, MA: Addison Wessley Longman.

Haskins, C. (2010), International Council on Systems Engineering, In: Systems engineering handbook: A guide for system life cycle processes and activities. Seattle, WA: INCOSE. (Ver. 3.2).

Hise, R. T. and Groth, J. C. (1995), "Assessing the risks new products face", Research Technology Management, Vol.38, No.4, pp. 37-41.

Hulbert, M., Feely, L., Inman, E., Johnson, A., Kearney, A., Michaels, J., Mitchell, M. and Zour, E. (2011), "Risk management in the pharmaceutical product development process", Journal of Pharmaceutical Innovation,Vol.3, No.4, pp.227-248.

ISO (2009): ISO 31000:2009(E) - Risk management - Principles and guidelines. Geneva: International Organization for Standardization.

Jerrard, B., Barnes, N. and Reid, A. (2009)," Researching creative companies: lessons learned from a risk in design project", Creative Industries Journal, Vol.2, No.4, 161-178.

Jiang, J. and Klein, G. (2000), "Software development risks to project effectiveness", Journal of Systems and Software, Vol. 52, No.1, pp. 3-10.

Kaplan, S. (1997) "The words of risk analysis", Risk Analysis, Vol.17, No.4, pp. 407-417.

Kaplan, S. and Garrick B. J. (1981) “On the quantitative definition of risk”, Risk Analysis, Vol. 1, No.1, pp.11-27.

Katsanis, L. P. and Pitta, D. (2006),"Managing the risk aspects of the product development process at the Upjohn Company", The Journal of Product and Brand Management,Vol. 15, No.4, pp. 250-254.

Keizer, J. A. and Halman, J. I. M. (2007), "Diagnosing risk in radical innovation projects", Research Technology Management, Vol.50, No.5, pp.30-36.

Keizer, J. A. and Halman, J. I. M. (2009), "Risks in major innovation projects: A multiple case study within a world's leading company in the fast moving consumer goods", International Journal of Technology Management, Vol.48, No.4, pp.499-517.

Keizer, J. A., Vos, J. P. and Halman, J. I. M. (2005), "Risks in new product development: Devising a reference tool", R and D Management, Vol.35, No.3, pp. 297-309.

Keizer, J.A., Halman, J.I.M. and M. Song, (2002), "From experience: Applying the risk diagnosing methodology RDM", The Journal of Product Innovation Management, Vol. 19, No 3, pp. 213-233.

Khan, O. and Creazza, A. (2009), "Managing the product design-supply chain interface Towards a roadmap to the design centric business", International Journal of Physical Distribution and Logistics Management, Vol. 39, No. 4, pp. 301-319.

Khan,O., and Burnes B. (2007), "Risk and supply chain management: Creating a research agenda", International Journal of Logistics Management,Vol. 18, No.2, pp.197-216.

Kwak, Y. H. and Stoddard, J. (2004), "Project risk management: lessons learned from software development environment", Technovation, Vol.24, No.11, pp. 915-920.

Lam, P. (2005), "Identifying and prioritizing critical success factors for conflict management in collaborative new product development", Industrial Marketing Management, Vol.34, No.8, pp.761-772

Kit. L., Chin, K. S. and Pun, K. F. (2007), "Managing conflict in collaborative new product development: A supplier perspective", The International Journal of Quality & Reliability Management, Vol.24, No.9, pp. 891-907

Lee, R. P. and Johnson, J. L. (2010), "Managing multiple facets of risk in new product alliances", Decision Sciences,Vol. 41, No.2, pp. 271-300.

Li, J., Conradi, R., Slyngstad, O. P., Torchiano, M., Morisio, M. and Bunse, C. (2008)," A state-of-the-practice survey of risk management in development with off-the-shelf software components", IEEE Transactions on Software Engineering, Vol.34, No.2, pp. 271-286.

Lockstrom, M., Schadel, J., Moser, R. and Harrison, N. (2011), "Domestic supplier integration in the Chinese automotive industry: The buyer's perspective", Journal of Supply Chain Management, Vol. 47, No.4, pp. 44-63.

Lough, K. G., Stone, R. and Tumer, I. Y. (2009), "The risk in early design method", Journal of Engineering Design, Vol.20, No.2, pp. 155-173.

Lupton, D. (1999), Risk, Routledge, London.

Lynne P, C. (2003), "A research agenda to reduce risk in new product development through knowledge management: A practitioner perspective", Journal of Engineering and Technology Management, Vol.20, No.1-2, pp.117-140.

Maass, E. and Mcnair, P. D. (2010), Applying design for six sigma to software and hardware systems, Upper Saddle River, NY: Prentice Hall.

McConnell, S. (1996), Rapid development, Microsoft press Redmond, Wash.

McManus, H. and Hastings, D. (2006), "A framework for understanding uncertainty and its mitigation and exploitation in complex systems", IEEE Engineering Management Review, Vol. 34, No. 3, pp. 81-94.

Meyer, A., Loch, C. H. and Pitch, M. T. (2001)," Managing project uncertainty: From variation to chaos", MIT Sloan Management Review, Vol.43, No.2, pp.60-68.

Miller, K. (1991), "A framework for integrated risk management in international business", Journal of International Business Studies, Vol. 23, No. 2, pp. 311-31.

Millward, H. and Lewis, A. (2005), "Barriers to successful new product development within small manufacturing companies", Journal of Small Business and Enterprise Development, Vol.12, No.3, pp. 379-394.

Mitchell, V. (1999), "Consumer perceived risk: Conceptualizations and models", European Journal of Marketing, Vol. 33, No. 1/2, pp. 163-195.

Montoya-Weiss, M. M. and Calantone, R. (1994), "Determinants of new product performance: A review and meta-analysis", Journal of Product Innovation Management, Vol.11, No.5, pp. 397-417.

Moore, P.G. (1983), The Business of Risk, Cambridge University Press, Cambridge.

Mu, J., Peng, G. and Maclachlan, D. L. (2009), "Effect of risk management strategy on NPD performance", Technovation, Vol.29, No.3, pp.170-180.

NASA (2008): Agency Risk Management Procedural Requirements, NASA Office of Safety and Mission Assurance.

Norman, A. and Lindroth, R. (2004), "Categorization of supply chain risk and risk management", In: Brindley, C. (Ed.), Supply Chain Risk, Ashgate, Aldershot

Oehmen, J. and Rebentisch, E. (2010), Risk management in lean PD. In: LAI Paper Series "Lean Product Development for Practitioners", Cambridge, MA, LAI and MIT

Oehmen, J. and Seering, W. (2011), Risk-Driven design processes: Balancing efficiency with resilience in product design. In: The Future of Design Methodology. London: Springer.

Oehmen, J., Dick, B., Lindemann, U. and Seering, W. (2006), “Risk management in product development: Current methods”. In*:* Proceedings of the International Design Conference, Dubrovnik, Croatia.

Oehmen, J., Ben-Daya, M. and Khan, O. (2010),

Oehmen, J.(2005), Approaches to crisis prevention in lean product development by high performance teams and through Risk Management. Diploma Thesis. Technical University of Munich.

Oehmen, J., Ben-Daya, M., Seering, W. and Al-Salamah, M. (2010b), "Risk Management in Product Design: Current State, Conceptual Model and Future Research", In: ASME Conference Proceedings, pp.1033-1041.

Ogawa, S. and Piller F. T. (2006),"Reducing the risks of new product development", MIT Sloan Management Review, Vol.47, No.2, pp. 65-71.

Olechowski, A., Oehmen, J., Seering, W. and Ben-Daya, M. (2012)," Characteristics of successful risk management in product design", International Design Conference - Design Dubrovnik - Croatia, May 21 - 24.

Omera, K., Martin, C. and Bernard, B. (2008)," The impact of product design on supply chain risk: a case study", International Journal of Physical Distribution and Logistics Management,Vol. 38, No.5, pp. 412-432.

Palousis, N., Luong, L. and Abhary, K. (2010)," Sustainability risk identification in product development", International Journal of Sustainable Engineering,Vol. 3, No.2, pp. 70-80.

Park, Y. H. (2010), "A study of risk management and performance measures on new product development", Asian Journal on Quality, Vol.11, No.1, pp. 39-48.

PMI (2008): Project Management Institute - A guide to the project management body of knowledge (PMBOK® Guide). Newtown Square, Pa.: Project Management Institute.

Raz, T., Shenhar, A. J. and Dvir, D. (2002), "Risk Management, project success, and technological uncertainty", R and D Management, Vol.32, No.2, pp. 101-109.

Ragatz, G. L., Handfield, R. B. and Petersen, K. J. (2002), "Benefits associated with supplier integration into new product development under conditions of technology uncertainty", Journal of Business Research, Vol. 55, No.5, pp. 389-400.

Rebecca, A. (2001), "The perspective of suppliers on lean supply in a developing country context", Integrated Manufacturing Systems, Vol.12, No.2, pp.87-94.

Reich, Y., and Paz, A. (2008), "Managing product quality, risk, and resources through resource quality function deployment", Journal of Engineering Design, Vol.19, No.3, pp. 249-267.

Risk Management Standard (1999), Risk Management Standard AS/NZS 4360, Standards Association of Australia, Sydney.

Rowe, W. (1980), "Risk assessment: Approaches and methods", In: Conrad, J. (Ed.), Society, Technology and Risk Assessment, Academic Press, London.

Royal Society (1992), Risk: Analysis, Perception and Management, Royal Society, London.

Royer, P. (2000), "Risk management: The undiscovered dimension of project management", Project Management Journal, Vol. 31 No.1, pp. 6-13.

Scacchi, W. (2002), Process models in software engineering. In :Encyclopaedia of Software Engineering, 2nd Edition. New York: John Wiley and Sons.

Schwaber, K. (1995), Scrum development process, Business Object Design and Implementation.

Segismundo, A. and Miguel P. A. C. (2008),"Risk management in the development of new products: A review and classification of literature", Product: Management and Development, Vol. 6, No.1 , pp.45-49.

Segismundo, A. and Miguel P. A. C. (2008),"Failure mode and effects analysis (FMEA) in the context of risk management in new product development", The International Journal of Quality and Reliability Management, Vol.25, No.9, pp. 899-912.

Shashank, R. and Thomas, J. G. (2009), "Supply chain risks: A review and typology", International Journal of Logistics Management,Vol. 20, No.1, pp.97-120.

Simon, P., Hillson, D. and Newland, K. (1997), Project Risk Analysis and Management Guide (PRAM), Association for Project Management, Norwich.

Slack, N. and Lewis, M. (2001), Operations Strategy, 3rd ed., Prentice-Hall, Harlow.

Smith, P. G. (1999), "Managing Risk as Product Development Schedules Shrink", Research-Technology Management, Vol.42, No.5, pp. 25-32.

Smith, P.G. (2003), "A portrait of risk", PM Network, April issue, pp. 44-48.

Snider, H. (1991), "Risk management: A retrospective view", Risk Management, Vol.38, No.4, pp. 47-54.

Sommer, S. C., Loch, C. H. and Pitch, M. T. (2008), Project risk management in new product development. In: Loch, C. H. et al.: The Handbook of New Product Development Management. Oxford: Elsevier, pp. 439-465.

Song, M. and Montoya-Weiss, M. M (2001), "The effect of perceived technological uncertainty on Japanese new product development", The Academy of Management Journal, Vol.44, No. 1, pp. 61-80.

Spira, L. F., and Page, M. (2002), "Risk Management - The reinvention of internal control and the changing role of internal audit", Accounting, Auditing and Accountability Journal, Vol.16, No.4, pp. 640-661.

Szwejczewski, M., Mitchell, R. and Lemke, F. (2008), "Risk measurement and management during new product development: An exploratory study", International Journal of Risk Assessment and Management, Vol. 9, No.3, pp. 277-287.

Tang, C. S.(2006)," Perspectives in supply chain risk management", International Journal of Production Economics,Vol. 103, No.2, pp. 451-488.

Tang, C. S., Zimmerman, J. D. and Nelson M.S, J. I. (2009), "Managing new product development and supply chain risks: The Boeing 787 Case", Supply Chain Forum: An International Journal, Vol.10, No.1, pp. 74-86.

Tranfield, D., Denyer, D., and Smart, P. (2003) "Towards a methodlogy for developing evidence informed management knowledge by means of systematic review", British Journal of Management, Vol.14, No.3, pp.207-222.

Thomas E, J. (2009), "Supplier involvement in new product development and innovation: Taking stock and looking to the future", Journal of Purchasing and Supply Management, Vol.15, No.3, pp.187-197.

Ulrich, K.and Eppinger, S. (2012) Product design and development. McGraw-Hill Higher Education.

Unger, D. and Eppinger, S. (2009) "Comparing product development processes and managing risk", International Journal of Product Development, Vol. 8, No. 4, pp.382-402.

Unger, D. and Eppinger, S. (2011), "Improving product development process design: A method for managing information flows, risks, and iterations", Journal of Engineering Design, Vol. 22, No.10, pp. 689-699.

Unger, D. W. (2003), Product development process design: improving development response to market, technical, and regulatory risks, Ph.D. Thesis. Cambridge, USA: Massachusetts Institute of Technology.

Wang, J. and Lin, Y. (2009)," An overlapping process model to assess schedule risk for new product development", Computers and Industrial Engineering,Vol. 57, No.2, pp. 460-474.

Wang, J .and Yang, C.Y. (2012), "Flexibility planning for managing R&D projects under risk", International Journal of Production Economics, Vol.135, No.2, pp. 823-831.

Wang, J., Lin, W. and Huang, Y.H. (2010), "A performance-oriented risk management framework for innovative R&D projects", Technovation, Vol.30, No.11-12, pp. 601-611.

Wang, L., Ming, X. G., Kong, F. B., Li, D. and Wang, P. P. (2011)," Focus on implementation: A framework for lean product development", Journal of Manufacturing Technology Management, Vol.23, No.1,pp. 4-24.

Water, D.(2007), Supply chain risk management:Vulnerabilities and resilience in logistics,Kogan Page, London.

White, D. (1995), "Application of system thinking to risk management: A review of the literature", Management Decision, Vol. 33, No. 10, pp. 35-45.

Wu, D. D., Kefan, X., Gang, C. and Ping, G. (2010), "A risk analysis model in concurrent engineering product development", Risk Analysis, Vol.30, No.9, pp. 1440-1453.

Yang, K. Ei-haik, B. S., Yang and K. El-haik, B. (2009), Design for six sigma: A roadmap for product development , In: Aufl. New York: Mcgraw-Hill Professional, Mcgraw-Hill

Yates, J.F. and Stone, E.(1992), "The risk constructs", in Yates, J.F. (Ed.), Risk taking behavior, Wiley, Chichester.

Yong, L. and Li, Z. (2011)," The impacts of product design changes on supply chain risk: A case study", International Journal of Physical Distribution and Logistics Management, Vol.41, No.2, pp. 162-186.

Zsidisin, G.A., Ellram, L.M., Carter, J.R. and Cavinato, J.L. (2004), "An analysis of supply risk assessment techniques", International Journal of Physical Distribution and Logistics Managent,Vol.41, No.4, pp.44-57

Appendix A Literature classification according to RM process

Author	RM Process		
	Identification	Assessment	Treatment
Oehmen et al. (2010b)	X	X	X
Oehmen et al. (2006)	X	X	X
Segismundo and Miguel, (2008)	X	X	X
Ahmed et al. (2007)	X	X	X
Jiang and Klein, (2000)			
Li et al., 2008			
Olechowski et al.(2012)			
Zsidisin and Smith, (2005)	X		X
Tang et al. (2009)			X
Keil et al. (1998)	X		
Dey et al. (2007)	X	X	X
Kit et al.(2007)			X
Lam,(2005)			X
Goodman et al. (2007)	X	X	X
Segismundo and Miguel, (2008)			X
Lockstrom et al.(2011)	X		
Rebecca, (2001)	X		
Lin and Zhou, (2010)	X		
Katsanis and Pitta, (2006)	X	X	X
Keizer et al. (2002)	X	X	X
Keizer and Halman, (2009)	X		
Keizer et al. (2005)	X		
Ogawa and Piller, (2006)			X
Khan et al.(2008)	X	X	X
Unger and Eppinger, (2011)			
(Szwejczewski et al., 2008)			
Mu et al. (2009)			
Chin, (2004)	X		X
Wognum et al.(2002)	X		
Smith, (1999)	X	X	X
Raz et al. (2002)			

(Abetti and Stuart, 1988)		X	
Coppendale, (1995)	X	X	X
Jerrard et al. (2008)	X		
Lee and Johnson, (2010)			X
Ragatz et al. (2002)	X		
Khan and Creazza, (2009)			X
De Meyer et al. (2002)	X		
Gosnik, (2011)	X	X	X
Katsanis and Pitta, (2006)	X	X	X
Millward and Lewis, (2005)	X		
Choi and Ahn, (2010)		X	
Reich and Paz, (2008)			X
Wang and Lin, (2009)		X	
Browning et al. (2002)		X	
Oehmen et al. (2010a)			
Park, (2010)			X
Wang et al. (2010)	X	X	X
Wang and Yang, (2012)			X
Oehmen, (2005)	X	X	X
Cooper, (2003)			X
Hise and Groth, (1995)		X	
Davis, (2002)			
Chou and Chou, (2011)	X		
Unger and Eppinger, (2009)			
Bassler et al. (2011)			
Oehmen et al. (2011)	X	X	X
Dash,(2010)		X	
Royer, (2000)	X	X	X

Appendix B: Data Extraction Forms

Title	1) Comparing product development processes and managing risk
Article type	Theoretical and empirical
Focus	This article explains a variety of Product Development Processes (PDPs) and aims to help companies better design their own PDPs. This review examines PDP characteristics and explains different PDPs. how different PDPs address risk through product development iterations, integrations, and reviews Our research has two goals, both of which help to bridge the knowledge gap in existing literature and industrial decision making. First we seek to identify different PDPs and establish that variety exists. To do so, we define parameters that allow for evenhanded comparisons between PDPs. Second, we demonstrate how different PDPs can address different risks through integrations, iterations, and reviews. Our overall research goal is to help academics and business managers with the difficult task of identifying, comparing, and successfully designing PDPs for risk management.
Sample selection, size and characteristics	9 Companies, I manager per company , product development manager in some cases group team members
Industry type	Multinational firms in Multi sector, 5 of them belongs to software, remaining are aviation, auto and paper sectors
Country	USA
Data collection methods	Case study. Semi structured interview
Research Question	First we seek to identify different PDPs and establish that variety exists. To do so, we define parameters that allow for evenhanded comparisons between PDPs. Second, we demonstrate how different PDPs can address different risks through integrations, iterations, and reviews

NPD level	Overall process
NPD type	Both
NPD risks	Technical risks, market risks, schedule risks and financial risks
Main findings	Author shows PDPs as a risk management structure. With the help of different parameters of PDPs, different PDPs can manage different types of risks
Limitations	It is not clear how different risks faced by a certain company are mitigated? Similarly, the characteristics of design review, iterations and integration could have discussed more for justifying their risk management capability.
Description of linkages with other studies	Analyzing risk management as an intrinsic part of PD approaches takes a different view. [6] for example discuss the dimensions of „iterations" (from narrow iterations within a phase to comprehensive, cross-phase iterations) and „review" (from rigid reviews that are frequent with fixed requirements to less frequent flexible reviews with soft requirements) to contrast waterfall, spiral and hybrid PD approaches in terms of their management of risks. Instead of prescribing a specific process on how to manage risks, [7] introduces „four risk-driven design principles" that are solution-neutral and represent objectives or outcomes of successful risk management. These principles are: 1. Creating transparency regarding design risks; 2. Making risk-based decisions; 3. Minimizing uncertainty in design; and 4. Creating resilient PD systems.
Future research	

Title	2)A Comparison Of The Integration Of Risk Management Principles In Product Development Approaches
Article type	Theoretical and empirical
Focus	This paper analyses the extent to which four common product development approaches address risks (waterfall model, spiral development, design for six sigma, and lean product development). The objective is to discuss their specific strengths and weaknesses regarding risk management, in order to create the bases for an organization to choose the appropriate process and customize it to match its risk exposure.
Sample selection, size and characteristics	Not given
Industry type	Aerospace and defense industry
Country	US
Data collection methods	Interviews, surveys
Research Question	To what extent different PD frameworks manage risks
NPD level	Mostly design phase
NPD type	All types
NPD risks	Company internal uncertainties, supplier related uncertainty, customer related uncertainty, market and macroeconomic uncertainty, technology uncertainty
Main findings	The analysis shows that the existing PD processes only partially address the four principles of risk-driven design and that they have their specific strengths and weaknesses. The different PD approaches address markedly different types of uncertainties. The waterfall model with its well-planned phases, rigid reviews and focus on clear structure mostly addresses system integration and

	company-internal uncertainties. Contrary, the spiral model focuses on comprehensive cross-phase iterations, the integration of critical stakeholders throughout the process and flexible reviews after several stages to reduce the uncertainty of changing customer requirements or technology novelty. DfSS addresses a larger number of risk sources with omprehensive probability assessments. Lean PD has some weaknesses regarding volatile customer requirements. Compared to the spiral model, it is not designed to handle significant changes in customer requirements in later development phases due to its very efficiency-driven design approach. It is, however, very well suited to make sure that (current) customer requirements are understood well. All approaches show a general weakness to address competition, supplier or market/environmental uncertainties. If any of these uncertainties post significant risks, the processes must be customized to include the appropriate treatment actions. Form the theoretical discussion in this paper, a combination of a spiral development with Design for Six Sigma methods yields the most comprehensive risk management oriented PD process.
Limitations	Limited to defense sector, US region, results are not explicit , sample size not given
Description of linkages with other studies	Analyzing risk management as an intrinsic part of PD approaches takes a different view. [6] for example discuss the dimensions of „iterations" (from narrow iterations within a phase to comprehensive, cross-phase iterations) and „review" (from rigid reviews that are frequent with fixed requirements to less frequent flexible reviews with soft requirements) to contrast waterfall, spiral and hybrid PD approaches in terms of their management of risks. Instead of prescribing a specific process on how to manage risks, [7] introduces „four risk-driven design principles" that are solution-neutral and represent objectives or outcomes of successful risk management. These principles are: 1. Creating transparency regarding design risks; 2. Making risk-based decisions; 3. Minimizing uncertainty in design; and 4. Creating resilient PD systems. The purpose of this paper is to analyze how different PD approaches manage risks, not to compare different risk management processes as such. It therefore follows [7] to understand how risks are managed in the different PD approaches by comparing how and to what degree certain principles of risk-driven design are addressed.
Future research	How these individual NPD processes combined in effective way
Title	3)Improving product development process design: a method for managing

	information flows, risks, and iterations
Article type	Case study and literature review
Focus	This paper identifies key components of PDPs and demonstrates how PDPs can be designed and structured differently to manage different risks. The paper also proposes a PDP design method that companies can use to either select or design PDPs that best match their risk profiles.
Sample selection, size and characteristics	case study
Industry type	Multiple sector
Country	USA
Data collection methods	Case study with interviews with designers, managers and engineers
Research Question	
NPD level	Overall
NPD type	All
NPD risks	Market risk, technical risk, schedule risk
Main findings	Author proposes a PDP design methodology based on the specific characteristics of design reviews and iterations. The idea is to match the risk of each PDP with the design review and iteration.
Limitations	The design metholdogy was implemented to one single case. Results were even not collected to verify whether it remained successful or not
Description of linkages with other studies	Analyzing risk management as an intrinsic part of PD approaches takes a different view. [6] for example discuss the dimensions of „iterations" (from narrow iterations within a phase to comprehensive, cross-phase iterations) and „review" (from rigid reviews that are frequent with fixed requirements to less

	frequent flexible reviews with soft requirements) to contrast waterfall, spiral and hybrid PD approaches in terms of their management of risks. Instead of prescribing a specific process on how to manage risks, [7] introduces „four risk-driven design principles" that are solution-neutral and represent objectives or outcomes of successful risk management. These principles are: 1. Creating transparency regarding design risks; 2. Making risk-based decisions; 3. Minimizing uncertainty in design; and 4. Creating resilient PD systems. The purpose of this paper is to analyze how different PD approaches manage risks, not to compare different risk management processes as such. It therefore follows [7] to understand how risks are managed in the different PD approaches by comparing how and to what degree certain principles of risk-driven design are addressed.
Future research	Designing a NPD process that suits company own needs

Title	4)Effect of risk management strategy on NPD performance
Article type	Empirical Supported by Literature, and empirically grounded
Focus	We seek to address this research gap by explaining and empirically testing how risk management strategy affects NPD.
Sample selection, size and characteristics	217 firms were surveyed
Industry type	Chinese cross industry
Country	China
Data collection methods	Indepth field interviews and surveys
Research Question	Effect of risk management strategy on NPD performance
NPD level	NA
NPD type	All
NPD risks	Market risks, technical risks, organizational risks
Main findings	Technological, organizational and marketing risk and their interactions have strong influence on NPD projects both individually and interactively.
Limitations	Chinese context, Focused on three main types of risks We did not distinguish among the relative influences of technological, organizational, and marketing risks on the performance of NPD as suggested by Doering and Parayre (2000). Also, we did not gauge the effect of risk manage- ment strategy on different types of NPD (incremental or radical). We did not test under what circumstances and to what extent the risk management strategy has a positive impact on NPD performance. In addition, the data were from China, so we should be cautious about generalizing the results to other

	contexts.
Description of linkages with other studies	
Future research	It must be acknowledged that this research did not examine possible reverse causality; i.e., it did not assess the effect NPD performance might have on ensuring that initiatives occur to reduce technological, organizational, and marketing risk and uncertainty. For example, earlier NPD performance may stimulate managers to pay more attention to the risk factors of NPD. Future studies should examine risk management longitudinally within complex sets of strategies and managerial tactics to identify the most effective risk reduction methods for NPD.

Title	5)risk management in product design: current state, conceptual model and future research
Article type	Literature review
Focus	The goals of this paper are to review and summarize the literature in PD risk management; to explore whether the generic ISO risk management process is a sensible unifying framework and conceptual model to review and present the literature on risk management in PD; and to identify gaps in the current literature as possible future research opportunities.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	Secondary sources, scholarly databases
Research Question	to explore whether the generic ISO risk management process is a sensible unifying framework and conceptual model to review and present the literature on risk management in PD; and to identify gaps in the current literature as possible future research opportunities.
NPD level	All
NPD type	All
NPD risks	Possible sources of uncertainty, i.e. risk causes, are the company itself with its processes, people and technological resources; its partners and supply chain, such as suppliers, customers and service providers; as well as external factors, such as competitors and political, social or environmental forces.

Main findings	The review of the literature above has shown that all process elements are being addressed by the current literature, but to varying degrees.
Limitations	Examined various approaches and strategies only
Description of linkages with other studies	
Future research	This paper is limited in several important aspects: First, as discussed in the introduction, this is not a complete review of the PD risk management literature, although every effort has been made to include the papers relevant for the questions discussed here from our more extensive collection. Also, only the part of the ISO 31000 addressing the risk management process as such was discussed, both the risk management principles as well as the implementation framework remain excluded from this paper. The current PD literature could have been structured in many different ways, such as along risk sources or effects, along PD process stages or general PD process models.

Title	6)Characteristics Of Successful Risk Management In Product Design
Article type	Empirical paper
Focus	This paper makes a contribution to addressing the literature gap on evaluating the impact of risk management practices on program performance.
Sample selection, size and characteristics	227 firms
Industry type	Aerospace and defense sector
Country	USA
Data collection methods	Focus group, survey
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	This paper reported the findings of a survey among industry professionals with regards to product design risk management. Four dimensions of success in product design risk management were identified. 38 survey variables were identified which showed a significant difference between low and high performing projects in at least three of the four dimensions of performance. These 38 characteristics were sorted into seven categories and presented as key factors of successful risk management in product design: I. Organizational Design Experience; II. Risk Management Personnel and Resources; III. Tailoring and Integration of RM Process; IV. Risk-Based Decision Making; V. Specific Mitigation Actions, VI. Monitoring and Review; and VII. Remaining ISO Risk Management Principles. All seven categories show

	strong evidence not only for successful risk management practices, but also evidence that these practices positively affect overall program stability and the achievement of the program cost, schedule, performance and customer satisfaction targets. These results not only inform current practitioners on where to focus risk management efforts, but also contribute a first large-scale empirical evaluation of the impact of specific risk management practices on product development success.
Limitations	The following limitations are important to consider when interpreting results. The survey is taken post-program and so accurate recollection of program details may be difficult. The analysis relies on self-reported outcomes which could be biased by the experience of the respondent. The survey was self-administered online; to address potential misinterpretation of the questions, clear descriptions and examples were included throughout the survey and opportunities were given to comment on individual questions. There is the potential for self-selection bias, where those who chose to respond to the survey did so because of an already strong opinion about risk management. A preliminary check to avoid a bias in the analysis due to various factors (e.g. industries, roles, project size) was performed for this analysis; extensive statistical analysis to control for these variables was not yet performed.
Description of linkages with other studies	
Future research	

Title	7)Integrating Supply Chain Risks In Product Development: A Conceptual Framework
Article type	Conceptual paper
Focus	This paper develops a conceptual framework for integrating supply chain risks in product development.
Sample selection, size and characteristics	
Industry type	
Country	
Data collection methods	Existing databases and secondary literature
Research Question	to identify and discuss how decisions in product development influence supply chain risks.
NPD level	All
NPD type	All
NPD risks	Supply chain risks
Main findings	Based on this conceptual framework, we identify supply chain risks that originate in the five different stages of the generic PD process. Among those risks are different forms of dependency on suppliers; increased complexity of the supply chain; and misaligned incentives of key stakeholders.
Limitations	The proposed conceptual framework for integrating supply chain risks in product development is based on existing PD, RM, and case studies related to these topics from the literature. It is the intention of the authors to refine this framework and validate it through research collaboration with industry. This is an extremely vital next step in our research to make sure that this framework is relevant and useful to practitioners.

Description of linkages with other studies	
Future research	

Title	8)Extended Model of Managing Risk in New Product Development Projects
Article type	Empirical
Focus	The aim of this research was to study new product development (npd) projects-related risks and the literature in this field, as well as to develop a specific extended model of managing risks in NPN projects, which will consider the nature of npd projects.
Sample selection, size and characteristics	Not clear from the paper
Industry type	NA
Country	NA
Data collection methods	Survey
Research Question	Determine the impact factors related with risks of new product and new projects
NPD level	Design
NPD type	All
NPD risks	Schedule risk, technical risk, external risk, organizational risk, communication risk, location risk, resource risk, financial risk
Main findings	Research shows that undefined technical requirements for the product present an important risk related to the design uncertainty of the product. The more imprecise the technical requirements for the product before the project starts, the higher is the design uncertainty of the product after its development. Unclear project objectives have a significant effect on the time-delay of npd projects. The more imprecisely the project objectives are defined before the project starts, the greater is the timedelay on the npd project.

Limitations	No empirical findings for extended model of risk management No enough detail of statistical evidence Poorly written
Description of linkages with other studies	Identification of factors that influence design uncertainties of any npd project
Future research	

Title	9)A study of risk management and performance measures on new product development
Article type	Conceptual paper
Focus	The purpose of this paper is to analyze the management process considering risks and performances in developing new products.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	Secondary literature
Research Question	The purpose of this paper is to analyze the management process considering risks and performances in developing new products.
NPD level	
NPD type	
NPD risks	Internal risk (operational risks, technology risks, organizational risks) external risks (market risks and supplier risk)
Main findings	A three step risk management process 1) risk assessment, 2) risk management performance measure and risk reduction performance increase The timing of risk management and performance measures is important to the impact level of performance.
Limitations	No empirical evidence
Description of linkages with other studies	Integration of performance measure and risk management

Future research	

Title	10) A State-of-the-Practice Survey of Risk Management in Development with Off-the-Shelf Software Components
Article type	Empirical
Focus	. The survey investigated actual risk-management activities and their correlations with the occurrences of typical risks in OTS component-based development.
Sample selection, size and characteristics	133 software projects
Industry type	IT sector
Country	Europe , Norway, Italy and Germany
Data collection methods	\Survey
Research Question	Which Risk occurred more frequently than other in designing software components? Which risk reduction activities were performed most frequently Which risk reduction activities is deemed effective for avoiding particular risks
NPD level	Outsourcing components
NPD type	Software
NPD risks	Specific software related risks
Main findings	With the help of case studies, author found frequent risks occurred which are very specific for software Author further explore risk reduction strategies specific to software risks
Limitations	Not generalizable to other contexts
Description of linkages	

with other studies	
Future research	to examine several industrial projects by estimating the risk probabilities before the project starts, follow the execution of the project, and measure the occurrence of problems corresponding to the risks after the project has been completed. The purpose is to investigate the causal effects of selected risk-reduction activities on the occurrence of associated risks.

Title	11) A performance-oriented risk management framework for innovative R&D projects
Article type	Conceptual paper
Focus	develop a new risk management framework that aligns project risk management with corporate strategy and a performance measurement system to increase success rates of R&D projects and to accomplish the corporate strategic objectives.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	Secondary literature
Research Question	
NPD level	All
NPD type	ALL
NPD risks	
Main findings	This paper proposes a new risk management framework that aligns project risk management with corporate strategy and a performance measurement system to increase success rates of R&D projects and to accomplish corporate strategic goals. The balanced scorecard is used to identify major performance measures of an R&D organization based on the firm vision and strategy. Quality function deployment is adapted to transform organizational performance measures into project performance measures and a systematic procedure is developed for risk identification, assessment, response planning, and control. The proposed risk management framework enables an R&D

	project to be focused on achieving the corporate goals and provides a more effective way to identify, assess, analyze, and monitor R&D risks along the project cycle. The proposed methodology is illustrated with a drug development project.
Limitations	The model is tested only on hypothetical scenario. No empirical evidence is given
Description of linkages with other studies	Risk management with performance measurement and corporate strategy .Similarity with paper #9 in term of performance measure
Future research	Since the major cause of the risk is uncertainty which may lead to positive or negative outcomes future research will extend the current R&D risk management frame- work to manage both opportunities and threats, and study how to gain values from uncertainty based on the real options analysis . In addition, further study is required to investigate the effects of group decision making in the proposed risk management framework

Title	12) A framework for identifying software project risks
Article type	Practitioner perspective
Focus	What are the factors that software project managers perceive as risks and which of these factors do they consider most important? Can the risk factors be categorized in such a way as to provide insight into appropriate risk mitigation strategies?
Sample selection, size and characteristics	40 Software project managers
Industry type	Software sector
Country	Finland, Hong Kong, US
Data collection methods	Interviews
Research Question	
NPD level	All
NPD type	All
NPD risks	Lack of top management commitment, failure to gain user commitment, misunderstanding the requirement Customer mandate, scope and requirement, environment and execution
Main findings	Proposed a risk categorization framework based on the interviews taken by software project risks manager 1)Risk perceived to be most important often lie outside the direct control of the project manager

Limitations	
Description of linkages with other studies	Paper 10 which is more specific to software compare to this one. Risk identified in paper 10 could not be generalized but risk categorization framework in this paper can be generalized due to its simplicity and general nature
Future research	the effectiveness of different strategies for managing each type of risk needs to be carefully assessed.

Title	13) A Framework for NPD Processes Under Uncertainty
Article type	Modeling
Focus	This article proposes a framework for designing new product development (NPD) processes under various conditions of uncertainty.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	The framework is based on the results of a study in which the goals were to determine the conditions under which integrated product development processes are more favorable than traditional sequential processes in terms of development time (process start to finish time) and effort (person hours). The framework suggests how to design the process in terms of functional interaction (information sharing among NPD participants) and overlapping (parallel execution of activities) based on the level of uncertainty involved.
Limitations	
Description of linkages	

with other studies	
Future research	Future research should be focused on specifically determining how uncertainty can be reduced. As just one example, Thomke (1998) showed that uncertainty could be reduced by using simulation and experimentation; however, as a start, the definition and measurement of uncertainty needs to be standardized, as many authors have conceptualized uncertainty in different ways

Title	14) Flexibility planning for managing R&D projects under risk
Article type	Conceptual
Focus	The objective of this paper is to develop a flexibility planning methodology based on real option analysis to improve managerial flexibility for R&D projects.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	Market and technical risk , other risks are strategic risk, discovery risk, development risk, commercial risk, regulatory risks
Main findings	The proposed methodology identifies potential risks that may occur during every R&D stage. It also recognizes a cascading option structure to resolve the identified risks, and evaluates and selects adequate options that maximize the potential value of the project. Instead of using a traditional option pricing method, a dynamic programming model that considers multidimensional product performance and market payoff is used to evaluate the R&D project value.
Limitations	

Description of linkages with other studies	Incorporating flexibility planning in the NPD process to manage risk
Future research	Future research will extend the developed flexibility planning methodology to study the flexibility value of R&D project that contains parallel paths to explore market opportu- nities. In addition, the Monte-Carlo simulation can be integrated with the approach developed to further explore the impacts of uncertainty on the value of managerial flexibility.

Title	15) Risk Management in the Pharmaceutical Product Development Process
Article type	Practitioner
Focus	This paper examines the role of risk management in pharmaceutical product development in the context of patient safety and drug efficacy. Its objective is to contribute to building a common understanding of this quality risk management among the various functional groups involved in developing, testing, manufacturing, and approving of drug products within pharmaceutical companies and regulatory agencies
Sample selection, size and characteristics	4 case studies
Industry type	Pharmacy
Country	USA
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	Acceptable risk, potential risk, significant risk, unacceptable risk
Main findings	1) Prior knowledge, experience, and scientific judgment can be utilized in conducting risk assessments to understand the relationships between inputs and outputs, which can help to determine if, when, and where to apply experimental investigation. (Noting that not all relationships need be subjected to experimental investigation.) 2) The importance of "acceptable risk" versus "no risk" is already established in ICH Q9 and is a theme that will be illustrated and further reinforced in this paper. Risk acceptance is determined in the context of the risk-tobenefit ratio for the patient. Thus, for example, the criteria for risk acceptance* may be much less restrictive for pharmaceuticals that treat life-threatening illnesses for which there are poor or no alternative treatments than for those that treat less

	severe illnesses for which alternative treatments exist. 3) Various approaches can be taken to manage risk, and it is not the approach that is taken that is important, but whether it effectively manages the risks. 4) Risk management is an ongoing process that requires periodic reassessments during development and continues through marketing and the entire product lifecycle*. Reassessment of risk is particularly important whenever significant changes are made to the product or associated manufacturing process.
Limitations	
Description of linkages with other studies	Risk assessment
Future research	

Title	16) Design, Risk and New Product Development in Five Small Creative Companies
Article type	Empirical
Focus	How is risk assessed in small companies when critical design decisions are made? 2. What kind of communication exists among the design team and the decision makers during the process of New Product Development? 3. What is the perceived weight of importance given to decisions made 'live' against a reflection over those same decisions at a later stage? 4. Is it possible to map the considerable literature based on management of risk in general management to the design function in creative companies? 5. Is it more appropriate to establish design as an integrated feature where risk is shared between decision 'locations'? 6. Should we acknowledge that creativity in the design of new products is delightfully risky and defies a description? 7. What is the nature of risk sharing between designer's decisions and those made by consumers?
Sample selection, size and characteristics	
Industry type	5 manufacturing companies
Country	UK
Data collection methods	Semi structured interviews and other secondary data
Research Question	
NPD level	Design

NPD type	All
NPD risks	Financial, personal, intellectual property, regulatory compliance, market, technical, partnership/collaboration and organizational
Main findings	Identify various types of risks
Limitations	
Description of linkages with other studies	
Future research	

Title	17) Risk analysis models and risk degree determination in new product development: A case study
Article type	Modeling
Focus	This paper proposes a risk analysis model to determine the risk degrees of the risk factors occurring in product development processes.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	NA
NPD type	NA
NPD risks	
Main findings	This paper suggests a new systematic risk management framework (RMF), as shown in Fig. 2. RMF determines risk degrees for risk factors and total risk degrees of the product development project, and shows effective and efficient responding activities. Especially, RMF suggests a risk analysis model under a concurrent engineering (CE) environment. CE is an approach to link all functional areas such as manufacturing, financing and marketing with the design process (Savic and Kayis, 2006). There is a multidirectional exchange of information among all functional areas for better, easier, and more economical product development. Therefore, either a high degree of collaboration or a high concurrency level (CL) is desirable to construct the CE environment. Furthermore, the fluent information exchange under high CL

	enables the functional areas to handle the related risk factors more effectively and efficiently. The increasing difficulties of a product development project require a higher CL. In addition, a full understanding of the pitfalls and risks is required for successful CE implementation. The famous pitfalls include unobtainable-schedule, change-product-ineffectiveteam, requirements, business-as-usual vendoring, automate-everything, supplier dependent leadtime, teams unsupported by reward systems, lack of information technology support project development instead of process improvement, and discontinued change (Willaert et al., 1998). In this case study, the risk analysis model is used to determine CL on a CE basis, and the model quantifies the influence of a risk factor to the development project as an impact value. When a risk factor occurs in a functional area, process, department or project, its impact value or the amount of influence differs. Therefore, the impact value has to be defined precisely. This paper proposes the use of fuzzy theory for this purpose. Because a risk factor occurs probabilistically or stochastically, a Markov process can be adopted to determine the probability of occurrences for a given risk factor. Finally, the developed risk analysis model is used to compute the risk degrees by multiplying the probability of occurrences with the impact value.
Limitations	
Description of linkages with other studies	
Future research	Further study is required to construct a robust RMF. New algorithms must be developed to compute the total risk degrees of the entire system. Especially, all possible functions and algorithms must be investigated for optimized application to and development of Eqs. (9)–(12) in the near future. The algorithm should also include a method to determine the minimum total risk degree in a development project by using the proper decision-making criteria. Furthermore, the performance of the risk analysis model must be verified by application to real industries. Finally, a huge volume of accurate data from real industries is needed to develop a more reliable, Markov-based model.

Title	18) From experience: applying the risk diagnosing methodology
Article type	Practitioners
Focus	In this article we will describe how Unilever, one of the world's leading companies in fast-moving consumer goods, adopted RDM after a major project failure in the midnineties.
Sample selection, size and characteristics	Not given
Industry type	FMCG
Country	Europe
Data collection methods	Interviews
Research Question	
NPD level	All
NPD type	All
NPD risks	Product family and brand positioning risk, product technology risk, manufacturing technology risk, intellectual property risks, supply chain and sourcing risk, consumer acceptance risk, trade customer risk, competitors risk, commercial viability risk, organizational and project management risk, public acceptance risk, screening and appraisal
Main findings	A three step risk diagnosing methodology was implemented. Risk identification, Risk assessment, risk response development and control At Unilever, RDM proved very useful in diagnosing project risks, promoting creative solutions for diagnosed risks and strengthening team ownership of the

	project as a whole. Our results also show that RDM outcomes can be used to build a knowledge base of potential risks in product innovation projects.
Limitations	
Description of linkages with other studies	
Future research	

Title	19) Diagnosing risks in product-innovation projects
Article type	Practitioners
Focus	
Sample selection, size and characteristics	
Industry type	Glass parts/ lighting industry
Country	
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	Technological, organizational and commercial risks
Main findings	Author proposed a risk diagnosing methodology consist of following steps: Identification of project risks, Valuation of project risks, decision making about the diagnosed risks, drawing up and execution of a risk management plan In identification of project risks, following steps are followed. 1) description of product, process, equipment and production system, 2) identification of technological gap, 3) identification of organizational and commercial gap Valuation of project risk: 1) evaluation of risk factors via risk questionnaire, 2) drawing up a risk topography and 3) quantifying risk for a project as a whole Decision making about diagnosed risks

	Once risk identified and evaluated, it can be analyzed through individual preparation, preparation by subgroups and plenary session. After that any of these strategy can be adopted. Reduce, transfer, reject, accept. Author concluded that method can be usefully applied in several stages of product creation process. However, the most powerful contribution can be achieved at the end of feasibility phase of product creation process. At this stage, the transition to the actual development and engineering of one product take place. RDM offers two ways for looking at interdependencies between risks. First the risks relating to various technical aspects can be analyzed in relation to each other. Second, the focus can be on the relationship between technical, organizational and commercial risks. RDM Advantages over existing risk methods
Limitations	
Description of linkages with other studies	Strongly linked with paper 18. As paper 18 is the continuation of the paper 19 .
Future research	

Title	20) Risk-Driven Design Processes: Balancing Efficiency with Resilience in Product Design
Article type	Book chapter conceptual
Focus	
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	
Research Question	
NPD level	Design
NPD type	All
NPD risks	Company internal uncertainty, Supplier uncertainty, customer requirement uncertainty, market uncertainty, technology uncertainty
Main findings	Risk-Driven Design places a different emphasis on the management of the design process than conventional efficiency-driven design (see Figures 1 and 3). When the design process is driven by the intention to manage risk, uncertainties and their effect on the objectives are identified and quantified. Decision making then focuses on risks, usually the most critical first. This is done by reducing the level of uncertainty as much as reasonable and then creating a resilient PD system that can absorb the residual uncertainty to achieve the objectives within the target range. 1) Creating transparency regarding design risks Identify and quantify uncertainties and risks 2) Making risk driven decisions 3) Minimizing uncertainty in design (reduce internal and external uncertainty)

	4) Creating resilience in the design system (create agile design system and critical buffer in the design system)
Limitations	
Description of linkages with other studies	
Future research	

Title	21) risk management in product development current methods
Article type	Conceptual paper / literature review
Focus	To review and discuss current methods in the area of risk management in product development
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	Secondary
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Risk identification: identification by failure modes, checklists qualitative risk analysis: risk scenarios, 5 whys, quantitative risk analysis: definition of general scales for impact likelihood and time component of risk, risk matrix for likelihood and impact risk prioritization: pareto analysis, top 10 risk ranking, monitoring of risks: "numbers of risk development path, scenario based tracking of risks aggregation of risks: total risk scenario Combined method: browning performance risk management method

Limitations	
Description of linkages with other studies	
Future research	

Title	22) Failure mode and effects analysis (FMEA) in the context of risk management in new product development A case study in an automotive company
Article type	Empirical
Focus	Effectively managing risk is an essential element of successful project management. In this sense, the present study seeks to propose a systematisation of technical risk management through the use of FMEA to optimise the decision making process in new product development (NPD).
Sample selection, size and characteristics	NA
Industry type	Automotive sector
Country	Brazil
Data collection methods	Case study through participants observation and document analysis
Research Question	
NPD level	overall
NPD type	Automotive
NPD risks	Technical risk
Main findings	Results included a reduction in the number of project and test planning loopings as well as a reduced number of prototypes needed to approve product components. In addition, there was a positive influence on the product development decision-making process, evidenced by better allocation of resources among projects at the programme.
Limitations	
Description of linkages with other studies	

Future research	Future studies will include a statistical validation of the influence of technical risk management on the product development decision-making process.

Title	23) DIAGNOSING RISK IN RADICAL INNOVATION PROJECTS
Article type	Empirical
Focus	The aim of this study was to find out which risks are associated with radical innovation projects if a risk conceptualization is applied that specifically fits the characteristics of such projects.
Sample selection, size and characteristics	8 in depth radical innovation projects 114 interviews
Industry type	FMCG
Country	
Data collection methods	
Research Question	
NPD level	All
NPD type	Radical
NPD risks	Product family and brand positioning risk, product technology risk, manufacturing technology risk, intellectual property risks, supply chain and sourcing risk, consumer acceptance risk, trade customer risk, competitors risk, commercial viability risk, organizational and project management risk, public acceptance risk, screening and appraisal
Main findings	Following implications were proposed 1) Be conscious of ambiguous risk 2) Take an integrated perspective 3) Take a systematic rather than impulsive approach 4) Make use of risk facilitator 5) Learn from experience
Limitations	

Description of linkages with other studies	Linkage with paper 18 and paper 19
Future research	

Title	24) Barriers to successful new product development within small manufacturing companies
Article type	Empirical
Focus	The objective of the research is to identify and analyse the main barriers to new product development within small manufacturing companies.
Sample selection, size and characteristics	3 manufacturing companies
Industry type	Manufacturing
Country	UK
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Three generic managerial issues that impinge on new product development are identified: the influence of a dominant owner/manager; a focus on time and cost ahead of other key factors; and a failure to understand the importance of product design. This paper examines the performance of small manufacturing companies from the point of view of their application of design activities within the overall new product development process. The empirical findings from three case studies draw attention to the issues that such companies face in the resource-constrained environment within which they operate. In particular, they reveal that whilst approaches such as stage-gate development may be widely deployed in large companies, new product development in small companies is

	conducted in an ad hoc manner. This is characterised by insufficient planning, inadequate resources and inattention to design requirements, coupled with a resistance to change. A number of generic managerial issues have been identified – all arising from the detrimental impact of the dominant owner/manager.
Limitations	3 firms only
Description of linkages with other studies	
Future research	Assessment of large number of manufacturing groups in other regions as well

Title	25)Managing risk as product development shrink
Article type	Practitioner
Focus	To understand how companies improves success rates and performance by managing risk proactively
Sample selection, size and characteristics	
Industry type	Multiple sector
Country	USA
Data collection methods	Obervation
Research Question	
NPD level	
NPD type	
NPD risks	Technical risk and market risks
Main findings	The level of risk or exposure is the product of two factors: Its impact which is the severity of risk and the likelihood of occurance. We will never eliminate risks, but we can keep them under control on average. Furthermore, proactively managed risk will be far less disruptive then if we work in a reactive mood , ignoring the likelihood of occurance and and dealing with the damagewhen it occur
Limitations	
Description of linkages	

with other studies	
Future research	

Title	26) A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective
Article type	Conceptual
Focus	This paper presents a practioner view of the desired characteristics of tools to support NPD and suggests a research agenda for the use of knowledge-based tools from the perspective of balancing benefits and risks.
Sample selection, size and characteristics	NA
Industry type	NA
Country	
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	Intrinsic risk and extrinsic risks
Main findings	This paper presents a practioner view of the desired characteristics of tools to support NPD and suggests a research agenda for the use of knowledge-based tools from the perspective of balancing benefits and risks
Limitations	
Description of linkages with other studies	
Future research	

Title	27) Reducing the risk of new product development
Article type	Practitioner article
Focus	The use of collective customer commitment in reducing the risks of NPD
Sample selection, size and characteristics	
Industry type	Retail chain and clothing sector
Country	US
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	Product failure due to lack of effective marketing skills
Main findings	Collective customer commitment combines the ideas of postponement and mass customization
Limitations	
Description of linkages with other studies	
Future research	

Title	28) Managing the risk aspect of product development process at the Upjohn company
Article type	Practitioner's aspect
Focus	Implementation of RM in Pharmacy firm
Sample selection, size and characteristics	
Industry type	Pharmacy
Country	
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	Market risks and technology risks
Main findings	Various approaches used at several stages of RM program
Limitations	Limited Applicability
Description of linkages with other studies	
Future research	Generalization can be made

Title	29) Adding value in product development by creating information and reducing risk
Article type	Modeling
Focus	Understanding components of technical performance risk
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	
Research Question	
NPD level	NA
NPD type	NA
NPD risks	Performance risk and technical risk
Main findings	Proposed a methodology risk value method
Limitations	
Description of linkages with other studies	
Future research	Additional research is needed to explore further the impacts of iteration and rework on value and progress in the design process. When does it make sense,

	based on net customer value, to iterate a group of PD activities? Another research opportunity is to apply the risk value method within smaller PD activities, helping them ascertain the extent to which information should evolve before it is released (cf., [37] and [64]). Activities could first focus on reducing the risk of near-term deliverables to minimize rework for downstream activities.

Title	30) Applying new product development models to the performing arts: strategies for managing risk
Article type	Practitioners
Focus	
Sample selection, size and characteristics	
Industry type	Art/Painting Products
Country	
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	Impossibility of testing new products, planning limited life cycle , inability to stock the product, social risks
Main findings	Proposed a NPD model
Limitations	
Description of linkages with other studies	

Future research	

Title	31) A review of techniques for risk management in projects
Article type	Literature review
Focus	– This paper aims to provide a review of techniques that support risk management in product development projects using the concurrent engineering (CE) philosophy.
Sample selection, size and characteristics	
Industry type	
Country	
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	
Main findings	Risk management is an activity within project management that is gaining importance due to current business environment with a global focus and competition. The techniques reviewed in this paper are used on an ad hoc basis currently. A more risk focused approach is likely to result in an integration of several of these techniques, resulting in an increased effectiveness of project management.
Limitations	

Description of linkages with other studies	
Future research	

Title	32)Risk management : the undiscovered dimension of project management
Article type	Practitioner
Focus	RM in Project management
Sample selection, size and characteristics	
Industry type	NA
Country	USA
Data collection methods	Observation
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Proposed approaches for RM process
Limitations	
Description of linkages with other studies	
Future research	

Title	33) Risk management, project success and technological uncertainty
Article type	Empirical
Focus	extent of usage of some risk management practices in industry
Sample selection, size and characteristics	
Industry type	Multiple sector
Country	Israel
Data collection methods	Survey
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Author examine the extent of usage of some risk management practices, such as risk identification, probabilistic risk analysis, planning for uncertainty and trade-off analysis, the difference in application across different types of projects, and their impact on various project success dimensions. Our findings suggest that risk management practices are still not widely used. Only a limited number of projects in our study have used any kind of risk management practices and many have only used some, but not all the available tools. When used, risk management practices seem to be working, and appear to be related to project success. We also found that risk management practices were more applicable to higher risk projects. The impact of risk management is mainly on better meeting time and budget goals and less on product performance and specification. In this case, we also found

	some differences according levels of technological uncertainty. Our conclusion is that risk management is still at its infancy and that at this time, more awareness to the application, training, tool development, and research on risk management is needed.
Limitations	
Description of linkages with other studies	
Future research	Additional research is needed to explore further the impacts of iteration and rework on value and progress in the design process. When does it make sense, based on net customer value, to iterate a group of PD activities? Another research opportunity is to apply the risk value method within smaller PD activities, helping them ascertain the extent to which information should evolve before it is released Activities could first focus on reducing the risk of near-term deliverables to minimize rework for downstream activities.

Title	34) Risk management during new product development: An exploratory study
Article type	Empirical case study
Focus	Investigation how UK firms measured and managed risks
Sample selection, size and characteristics	8 case studies, Interview and semi structured questionnaire with senior managers from marketing and R&D functions
Industry type	Multiple sectors
Country	UK
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	Commercial and technical risks
Main findings	The analysis indicated that majority of UK firms carried out some form of risk assessment, but the degree of formality varied between the firms Several manager stressed the importance of risk assessment early at the NPD process which ensure that risks are identified at the start of the project. Few companies compared the risks across all the projects being worked on. Mostly risk assessment done on project by project basis
Limitations	
Description of linkages with other studies	

Future research	

Title	35) The impact of product design on supply chain risk: a case study
Article type	Empirical
Focus	Supply chain risk and its impact
Sample selection, size and characteristics	
Industry type	Clothing sector
Country	UK
Data collection methods	Interviews
Research Question	
NPD level	
NPD type	
NPD risks	
Main findings	This paper provides a framework for design-led supply chain risk management and thus presents a case for recognizing design as more than a creative function but as a platform to manage risk in supply chains.
Limitations	
Description of linkages with other studies	
Future research	The effect of design decisions on supply chains needs to be looked from a holistic,

	through-life perspective. In other words how will the design process itself, i.e. the way that designs are created and specific design decisions, e.g. sourcing, choice of materials, physical characteristics, etc. impact supply chain responsiveness and costs from the launch of the product to its end of life. The effect of design decisions on supply chains needs to be looked from a holistic, through-life perspective. In other words how will the design process itself, i.e. the way that designs are created and specific design decisions, e.g. sourcing, choice of materials, physical characteristics, etc. impact supply chain responsiveness and costs from the launch of the product to its end of life.

Title	36) Managing the product design-supply chain interface Towards a roadmap to the “design centric business
Article type	Empirical
Focus	The purpose of this paper is to investigate the interface between product design and the supply chain and to develop a roadmap to the design centric business through better management of this interface.
Sample selection, size and characteristics	3 multi sector firms
Industry type	Multi sector
Country	UK
Data collection methods	
Research Question	
NPD level	
NPD type	
NPD risks	
Main findings	The research shows that successful companies will be those which seek to extend and develop the contribution of design into all aspects of their business. The roadmap to a design centric business enables firms to better position product design within their business processes and helps facilitate better integration between product design and the supply chain.
Limitations	
Description of linkages with other studies	

Future research	

Title	37) Managing New Product Development and Supply Chain Risks: The Boeing 787 Case
Article type	Empirical
Focus	
Sample selection, size and characteristics	Single case
Industry type	Aerospace
Country	USA
Data collection methods	Secondary reports, observation
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Identified risks which causes delay in the manufacturing of Being 727 Proposed RM treatment strategies to overcome such obstacles in future
Limitations	No empirical evidence for the strategies
Description of linkages with other studies	
Future research	

Title	38) Managing Supply Risk with Early Supplier Involvement: A Case Study and Research Propositions
Article type	Empirical
Focus	Supplier related risks
Sample selection, size and characteristics	One case study
Industry type	Aerospace
Country	US
Data collection methods	Interviews
Research Question	
NPD level	Design
NPD type	All
NPD risks	
Main findings	Utilizing a case-study approach, the current research explores the extent to which ESI reduces the likelihood of supply disruptions and other negative supply events for an aerospace supplier. Although initial adoption of ESI was intended to reduce supply costs, results indicated that ESI serves to reduce perceptions of supply risk at this firm.
Limitations	Proposed prepositions are not validated
Description of linkages with other studies	

Future research	

Title	39) Software development risk to project effectiveness
Article type	Empirical
Focus	to examine the impact of the spectrum of risks on different aspects of system development.
Sample selection, size and characteristics	86 project managers
Industry type	Software electronics
Country	USA
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Common aspects of project effectiveness are generally under control, but are most effected by lack of expertise on the project team. Significant relationships also show that lack of clear role definition and conflicts on the team are also elevated risks. Other items are not as critical or limited to a much smaller aspect of effectiveness than overall success. This focusing in on the more important risk aspects will allow for more effective management of the project and a narrowing of techniques to mitigate the significant risks
Limitations	To software industry only

Description of linkages with other studies	
Future research	

Title	40) Managing product quality, risk, and resources through resource quality function deployment
Article type	Modeling
Focus	Risk at different design decisions
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	AN
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	we propose a new method that, based on a mathematical programming extension of quality function deployment, uses detailed information about the product and the organizational marketing and engineering competencies. The method outputs detailed information regarding project resource allocation, planned product quality, target market share, and resulting project risk that support the aforementioned decisions
Limitations	
Description of linkages with other studies	

Future research	We can extend the model further and test it in practical settings.It can also be interfaced it with other conceptual design tools.

Title	41) Managing product development risk
Article type	Practitioners
Focus	How Intel conduct RM for radical projects
Sample selection, size and characteristics	Single case
Industry type	Electroncis
Country	US
Data collection methods	Obervation
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	6 step RM cycle
Limitations	
Description of linkages with other studies	
Future research	

Title	42) The impacts of product design changes on supply chain risk: a case study
Article type	
Focus	The main purpose of this paper is to address the impact of product design changes on supply chain risk, and to identify the supply chain risk dimensions in the Chinese special-purpose vehicle (SPV) industry in the context of product design change.
Sample selection, size and characteristics	Case study methodology
Industry type	Automotive
Country	China
Data collection methods	Indepth and semi structured interviews
Research Question	
NPD level	Design
NPD type	All
NPD risks	
Main findings	This paper identifies both the internal and external supply chain risk from the perspective of the focal manufacturer in the SPV supply chain. At the level of the external supply chain, customer-required design change normally leads to risk in supply, delivery, and policy. Internally for the manufacturer, the risk dimensions are R&D, production, planning,

	information, and organization. All of these risk dimensions have their respective causes.
Limitations	
Description of linkages with other studies	
Future research	

Title	43) Managing project uncertainty
Article type	Practitioners
Focus	Project uncertainties and their management
Sample selection, size and characteristics	NA
Industry type	Multiple
Country	US
Data collection methods	Case study
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Provided Treatment approaches for various types of uncertainties
Limitations	
Description of linkages with other studies	
Future research	

Title	44) Risk in new product development: devising a reference tool
Article type	Case study
Focus	This paper describes the development and applicability of a risk reference framework (RRF) for diagnosing risks in technological breakthrough projects.
Sample selection, size and characteristics	8 cases
Industry type	FMCG
Country	Europe
Data collection methods	Semi structured interviews
Research Question	
NPD level	All
NPD type	All
NPD risks	Commercial viability risk, Competitor risks , Consumer acceptance and Marketing risks, Public acceptance risks, Intellectual property risks, Manufacturing technology risks, Organization and Project management risks, Product family and Brand positioning risks, Product technology risks, Screening and Appraisal risks, Supply chain and Sourcing risks, Trade customer risks
Main findings	the success of breakthrough innovation projects improves through formal risk assessment.
Limitations	

Description of linkages with other studies	
Future research	

Title	45) Risks in major innovation projects, a multiple case study within a world's leading company in the fast moving consumer goods
Article type	Empirical
Focus	Risks associated with radical innovation products
Sample selection, size and characteristics	Single
Industry type	FMCG
Country	Europe
Data collection methods	Semi structured interviews
Research Question	
NPD level	Overall
NPD type	Radical
NPD risks	
Main findings	Author identified many risks that were classified into Ambiguous and unambiguous risks
Limitations	
Description of linkages with other studies	
Future research	

Title	46) Evaluating new product risk
Article type	Practitioner
Focus	Examine component of risk and asses the product innovation uniqueness
Sample selection, size and characteristics	NA
Industry type	NA
Country	USA
Data collection methods	Observations
Research Question	
NPD level	All
NPD type	All
NPD risks	Market, function and technology risk
Main findings	Product risk increases with product newness and decreases with innovation uniqueness Timing for risk evaluation is very important. Too early risk evaluation may kill innovative ideas etc. Who should evaluate risk is another important decision How should risk be evaluated. Author proposed a step by step procedure for that.
Limitations	

Description of linkages with other studies	
Future research	

Title	47) Innovation outsourcing: Risks and quality issues
Article type	Conceptual
Focus	This paper discusses the issues related to innovation outsourcing, including uncertainty, risks, productivity and quality issues.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	Evolutionary (existing markets, existing technology): lowest risk, but possibly limited economic potential. • Leverage base (new markets, existing technology): somewhat higher risk. For a global economy, opportunities of this type tend to be geographical. • Discontinuous (existing markets, new technology): somewhat higher risk. This case refers to technology substitution, a familiar situation. • Radical (new markets, new technology): highest risk. If the market

	is large, this may offer the greatest opportunity. Technological risks, • Market risks, • Business environment risks, • R&D process risks, • Project size and management risks, • Customer risks, • Work force risks, and • Outsourcing life cycle encountered risk factors.
Main findings	Proposed some recommendations to tackle such kind of risks
Limitations	
Description of linkages with other studies	
Future research	

Title	48) Manage risk in product and process development and avoid unpleasant surprises
Article type	Practitioners
Focus	RM implementation
Sample selection, size and characteristics	
Industry type	Multiple sector
Country	UK
Data collection methods	Observation
Research Question	
NPD level	All
NPD type	All
NPD risks	External risks, project management risks, marketing risks, commercial risks, Manufacturing risk, technical risks,
Main findings	**Step 1: Identify the risks**, **Step 2: Assess the likelihood and the impact of potential risks, Step 3: Develop risk management plans**
Limitations	
Description of linkages with other studies	
Future research	

Title	49) Risk Assessment Techniques for Software Development
Article type	Conceptual
Focus	This paper focuses on the problem of how to manage risk in the software development.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	NA
NPD type	NA
NPD risks	
Main findings	We have discussed how Spiral model deals with the prevention and reduction of risks, continuously access all possible problems, define potential risks, and determine what risks are important and how to deal with them. Finally we have discussed some risk estimation method for software product development. Again we can conclude “the findings of this paper can be a project management tool to assess and tone down the events that might adversely affect a project, thereby increasing the possibility of success”.
Limitations	

Description of linkages with other studies	
Future research	

Title	50) Calculated risk: A framework for evaluating product development
Article type	Practitioners
Focus	Risk assessment in product portfolio
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	Marketing risk, User risk, Technical risk
Main findings	The NPVR framework creates a net present value that considers the impacts of product portfolio, user needs and technical and marketing risks.
Limitations	
Description of linkages with other studies	
Future research	

Title	51) Managing risk in software development projects: a case study
Article type	Conceptual embedded with single case study
Focus	The main objective of the paper is to develop a risk management framework for software development projects from developers' perspective.
Sample selection, size and characteristics	
Industry type	Public sector / software
Country	Barbados
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	This study uses a combined qualitative and quantitative technique with the active involvement of stakeholders in order to identify, analyze and respond to risks. The entire methodology has been explained using a case study on software development project in a public sector organization in Barbados. Analytical approach to managing risk in software development ensures effective delivery of projects to clients. RM framework 1) Analyzing functional requirements 2) Establishing scope of software development project and developing work breakdown structure

	3) Identify risky work package 4) Identifying risky events 5) Analyzing risks 6) Developing risk management plan 7) Controlling risks
Limitations	
Description of linkages with other studies	
Future research	

.

Title	52) Product Innovation Risk Management based on Bayesian Decision Theory
Article type	Modeling
Focus	The paper discussed how to use Bayesian Decision Theory to achieve quantitative innovation-risk management in product innovation: based on the description of three elements for product innovation risk management, the author discussed the process of bayesian risk decision-making in product innovation. Thus to providing references for scientific decision of innovation activities in enterprises.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	The paper discussed how to use Bayesian Decision Theory to achieve quantitative innovation-risk management in product innovation: based on the description of three elements for product innovation risk management, the author discussed the process of bayesian risk decision-making in product innovation. Thus to providing references for scientific decision of innovation activities in enterprises.
Limitations	

Description of linkages with other studies	
Future research	

Title	53) Assessing the risks new products face
Article type	Practitioner
Focus	Analyzing the external environmental risk of NPD for successful survival
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	All
NPD type	All
NPD risks	Market, competition, technology, political, social
Main findings	Author provided environemtnal scanning methodology based on aforementioned five dimensions of risks
Limitations	
Description of linkages with other studies	
Future research	

Title	54) Project risk management: lessons learned from software development environment.
Article type	Conceptual
Focus	. This paper addresses lessons learned from implementing project risk management practices in software development environment.
Sample selection, size and characteristics	
Industry type	
Country	
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	
Main findings	Implementing effective risk management process will succeed by changing the organizational culture
Limitations	
Description of linkages with other studies	
Future research	

Title	55) Managing Multiple Facets of Risk in New Product Alliances.
Article type	
Focus	we explore how key risk types intrinsic in new product alliances, performance, relational, and knowledge appropriation risks, influence alliance success.
Sample selection, size and characteristics	
Industry type	Multiple sector
Country	USA
Data collection methods	
Research Question	
NPD level	All
NPD type	All
NPD risks	performance risks, relational risks and knowledge appropriate risks.
Main findings	The article by (Lee and Johnson 2010) is purely theoretical knowledge research where authors have used different existing organizational and relationships theories to come across with three distinct types of risks; performance risks, relational risks and knowledge appropriate risks. The overall objective was to confirm the negative impact of these risks in the NPD success. Furthermore, two governance mechanisms were also selected as risk coping mechanism to above mentioned risks; explicit governance and normative governance mechanisms.
Limitations	

Description of linkages with other studies	
Future research	

Title	56) A risk analysis model in concurrent engineering product development
Article type	Modeling
Focus	This article analyzes various risks and challenges in product development under the concurrent engineering environment.
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	Na
Research Question	
NPD level	All
NPD type	All
NPD risks	Technology risk, Human resource risk, Financial risk, Organizational risk, Strategy risk, Risk of poor planning and control , schedule risk, quality risk and cost risk
Main findings	A threedimensional early warning approach for product development risk management is proposed by integrating graphical evaluation and review technique (GERT) and failure modes and effects analysis (FMEA). Simulation models are created to solve our proposed concurrent engineering product development risk management model. Solutions lead to identification of key risk controlling points. This article demonstrates the value of our approach to risk analysis as a means to monitor various risks typical in the manufacturing sector. This article has three main contributions. First, we establish a conceptual framework to classify various risks in concurrent engineering (CE)

	product development (PD). Second, we propose use of existing quantitative approaches for PD risk analysis purposes: GERT, FMEA, and product database management (PDM). Based on quantitative tools, we create our approach for risk management of CE PDand discuss solutions of the models. Third, we demonstrate the value of applying our approach using data from a typical Chinese motor company.
Limitations	
Description of linkages with other studies	
Future research	

Title	57) The risk in early design method
Article type	Modeling
Focus	relationship between function and risk in early design
Sample selection, size and characteristics	NA
Industry type	NA
Country	NA
Data collection methods	NA
Research Question	
NPD level	Design
NPD type	All
NPD risks	
Main findings	This study focuses specifically on the relationship between function and risk in early design by presenting a mathematical mapping from product function to risk assessments that can be used in the conceptual design phase. An investigation of a spacecraft orientation subsystem is used to demonstrate the mappings. The results from the study and its spacecraft application yield a preliminary risk assessment method that can be used to identify and assess risks as early as the conceptual phase of design. The preliminary risk assessment presented in this paper is a tool that will aid designers by identifying risks as well as reducing the subjectivity of the likelihood and consequence value from a risk element, will provide four key risk element properties (design parameter, failure mode, likelihood, and consequence) for numerous risk elements with simple calculations, and will provide a means for

	inexperienced designers to effectively address risk in the conceptual design phase.
Limitations	
Description of linkages with other studies	
Future research	